LINEAR ACTUATORS

Control2 *Smartbox*
Switching Module
Dual Joysticks

1100-05 Linear Actuators
Vacuum-compatible
Custom Servo and Cabling

Custom 24-axis
Linear Actuator
Motion System

IRONLESS-CORE DC MOTOR
STEPPING MOTOR

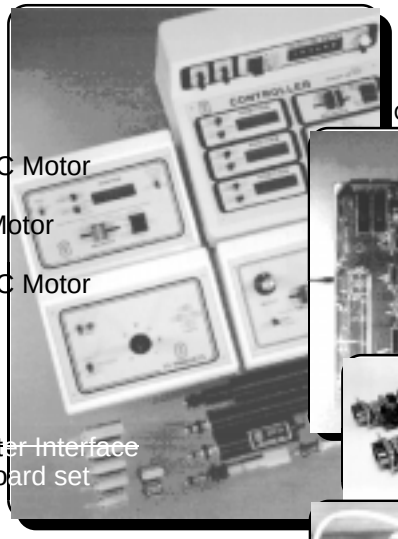
Diamond Motion, Inc.
P.O. Box 1225
Port Angeles, WA 98362-0227 USA
360-417-9791 Fax 360-417-9794

2000-Family
Stepping Motor Version

3.2-0398

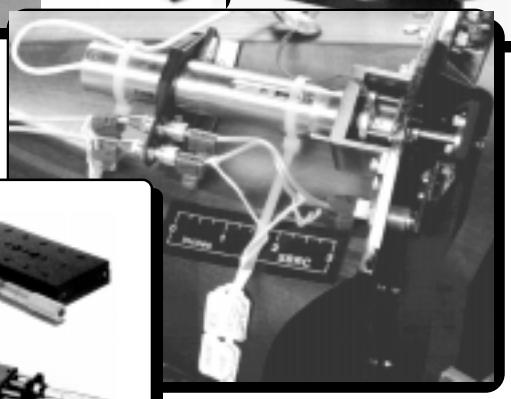
PRODUCT SUMMARY

- **ACTUATORS**
  - **LINEAR**
    - 1000-family Ironless-core DC Motor
    - 2000-family Stepping Motor
    - 3000-family Brushless DC Motor
  - **ROTARY**
    - 1400-family Ironless-core DC Motor
    - 2400-family Stepping Motor
- **DC-MOTOR LINEAR SERVOS**
- **CONTROLLERS**
  - **CLOSED-LOOP**
    - ~~Control2 *Smartbox*~~ ~~Computer Interface~~
    - Control3 *Smartboard* OEM board set
  - **HYBRID POSITION DISPLAY**
    - 1000INT Integrated
    - 1000MOD Modular
  - **OPEN-LOOP**
    - 1200SC Speed Controller
    - 1200J Joystick



Quintel Corporation
CONTROL3 *Smartboard*

United Technologies
Optical Systems
CONTROL2 *Smartbox*



Santa Barbara Research Center

TYPICAL USES

Wherever you might have used a *manual adjustment micrometer spindle*, you can substitute a **motorized Linear Actuator** for computer control of movement or precise remote manual control.

TASK	APPARATUS	COMPONENT	CUSTOMER
Point 91 sub-mirrors in Primary Mirror	HET Telescope	2200-1-AM1524-485	Univ. of Texas
Point a Photographic Camera Mirror	Earth Resources Satellite	1100-05-1616-485, 1000MOD	Santa Barbara Research Center
Position a Silicon Wafer	Q6000 Photomask Aligner	1100-05-1624-485, 1200-05-1624-76ZB, 1200-05-1616-262ZB, 1200-1-1616-262ZB, Control3, 1200J	Quintel Corporation
Direct a Mirror Forest	Optical Table with Mirror Mounts	1100-05-1616-1670-V, 1000C2-2	United Technologies Optical Systems
Position a Pressure Proximity Sensor	Robotic End Effector	1200-1-1724-3.71	Hobart Laser
Position an Atomic-Force Microscope Probe	Vertical Slide above sample	1100-05-1616-485ZB	Digital Instruments
Position an Optical Fiber in a production environment prior to final potting	Stacked X/Y/Z Slides	1000-05-1624-262, 1100-2-1624-11.8, Control2-4, 1200-025-1616-262, 1200JC	3M Corporation Fiber Optics Division
Position a Hybrid Memory Module in a prototype assembly laboratory under computer control	Translation slides and rotating shaft	1100-025-1616-141, 1100-05-1624-76, 1100-1-1624-22, 1100-2-1624-11.8 1100-4-1624-6.3, 1100-4-1624-22, 1400-1616-262 Control2-4, Control2-6	Texas Instruments
Rotate a Silicon Wafer	Rotate chuck tangent arm	1100-025-1616-76	Etec Corporation
Position a Disk Head Wafer for dicing	Crossed-roller slide under a grinding wheel in a wet environment	1000-1-1616-3101, Control2-2	Seagate Technology
Move a Sample at an ultra-slow velocity	Scanning Electron Microscope	1100-05-1624-19813ZB, 1100-1-1616-3101ZB, 1000INT	Lawrence Livermore National Laboratory
Adjust a Valve on a Test Motor	Tangent arm rotating a control shaft	2200-1-AM1524-41	General Motors Power Trans. Div.

Why use Motorized Linear Actuators instead of Manual Micrometers for Adjustment?

- Remote control
  You just can't easily reach the knob!
- Computer control
  Unattended simultaneous multi-axis motion control.
- Velocity control
  Adjust the velocity profile to fit your requirement.
- Total system consolidation
  Fully-computerized instruments.
- Leadscrew Pitch Error Compensation
  A look-up table removes periodic pitch errors.

What Industries Use Motorized Linear Actuators?

Since automation is creeping into every industry and personal computers sit on every desk, our customers cross many diverse fields –

- Semiconductor Manufacturing Equipment
- Medical Research
- Optical/Laser Equipment
- Photographic camera pointing platform
- Satellites with optics
- Anyone adjusting a control arm

Why use TS Products' Linear Actuators Compared to other Suppliers of In-line Motorized Actuators?

- Large selection of 2,374 configurations –

640	1000-series	Ironless-core DC Motor
1536	1100 and 1200-series	Stepping Motor
90	2000-series	
108	2100, 2200-series	

- High accuracy Leadscrew
  0.5µm runout over 4"
- Long-life mechanics
  - Dual anti-rotation tab to prevent self-induced sideload on the leadscrew.
  - Zero thrust on gearhead output shaft at limits-of-travel.
  - Internal elastomer cushions at ends-of-travel.
  - Polished Nose Button – short radius, long radius, flat.
  - Mating Push Pads.
  - Bellows option for leadscrew protection.
- Internal limit-of-travel and HOME Hall-effect sensors with overtravel.
- High thrust up to 300 lbs. with 1724 motor and 16/7 gearhead.
- Diminished backlash option.
- One price for any gearhead ratio.
- Custom modifications easy to get.
- PULL as well as PUSH with -PPA Push/Pull Adaptor.
- Vacuum compatibility to 10^{-9} Torr.
- Knowledgeable Customer Service by product designers.

Motorized Linear Actuator Alternative Sources

In-Line Motor, Low Thrust	Side-Mount Motor, High Thrust
•TS Products	•Industrial Devices
•Newport/Klinger	•Warner Electric
•Oriel	•Jordan Controls
•Melles-Griot	
•Physik Instrumente	

COMPARING THE COMPETITION

In the table below, we compare selected features of our Linear Actuators to five other suppliers.
(Please verify competitors' features.)

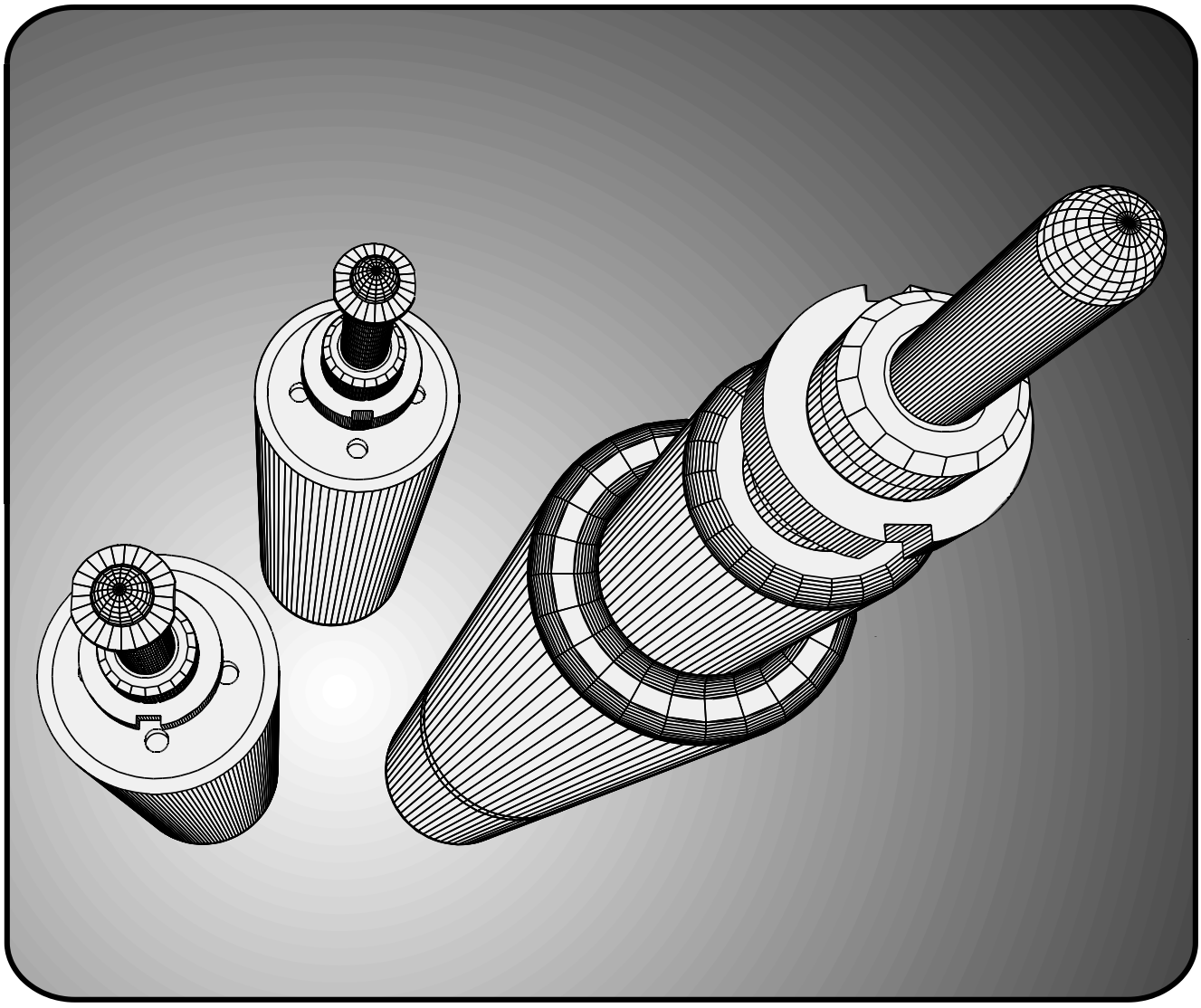
FEATURE	TS PRODUCTS	Newport/ Klinger	Oriel	Melles-Griot	Burleigh Instruments	New Focus
Basic Construction	In-line Motor/Encoder/Leadscrew inside 1" OD tube	Similar in-line construction. Rectangular PM500-A1 with glass scale	Similar in-line construction in 0.75" tube	Probably similar	Ganged piezoelectric washers move on rod	Clever Piezo Motor rotates screw by friction
Standard Micrometer Replacement?	Yes	Yes	Yes	Yes	Yes	No
Internal Limit-of-Travel Sensors?	• 1000-family (custom) • 2000-family (std.)	• 850/860 No • PM500-A1?	No	No	No	No
Principal Attributes						
Positive Attributes?	• Large selection • Custom Modifications • Rugged • Open and closed-loop • OEM/quantity discounts • Fast delivery • Knowledgeable Customer Support	• Open and closed loop	• Smaller OD • Open & closed loop	?	• High-resolution • Higher absolute accuracy • Zero backlash	• Small package • High resolution • Laser mirror positioning • Zero backlash
Negative Attributes?		• Limited selection • Weaker internal construction • Limited custom modifications • No OEM or quantity discounts?	• Less thrust • Weak motor • Self-constricting • Fragile construction • Variations?	?	• Open-loop uncertainty • High acoustic noise • Low thrust	• Open-loop uncertainty • Low thrust • Repeatability? • Acoustic noise?
Variations Available						
Vacuum Compatibility?	10^{-9} Torr (-V Option)	10^{-6} Torr	10^{-5} Torr	?	[2]	[2]
Gear Ratios	>32 3.71-235,067:1	Three 11.8, 262, 1670:1	One 485:1	One	na	na
Motor Styles	• Four Ironless-core DC • Stepping • Brushless DC	Two Ironless-core DC	One Ironless-core DC	One Ironless-core DC	na	na
Travels	¼"-12"	½"-4"	½"-2"	?	½"-2"	na
Resolution	2ρm-3.5µm	0.05µm std. 7.5ηm, 0.55µm	0.02µm	?	?	na
Maximum Thrust Limit	300 lbs.	100 lbs.	22 lbs.	?	15 lbs.[1]	?
Push and Pull?	Yes	No	No	No	[2]	[2]
Maximum Velocity Range	290ηm/sec-18mm/sec	75µm/sec-5.5mm/sec	0.2mm/sec	?	?	?
Pricing Philosophy	**One price** for all gearhead variations[3]	**Variable pricing** for three velocity variations	na	?	?	?
Design Engineering Support	• Detailed Drawings • AutoCad files • Designers provide customer service	• Catalog Information	?	?	?	?

[1] Estimated.
[2] Probably available.
[3] Within one style; all ratios.

na = Not applicable.
? = Not enough information to make a comparison.

CONTENTS

Introduction to Linear Actuators 1
DC-Motor 9
1000-series 10
1100-series 16
1200-series 20
Stepping-Motor 30
2000-series 32
2100-series 33
2200-series 34
Accessories 47
Pricing 52
Warranty 54



INTRODUCTION TO LINEAR ACTUATORS

COMPARATIVE FEATURES

Series	Electronic: Control Method	Electronic: Limit Sensing	Electronic: Current @ Stall[1]	Mechanical: Housing Length	Mechanical: Travel	Mechanical: Thruster Rotating?	Mechanical: Resolution	Mechanical: Maximum Velocity Range units/sec	Mechanical: Maximum Thrust lbs	Price @ ½" Travel
IRONLESS-CORE DC MOTOR								**1616**	**1616**	~~$1K~~
								1624	**1624**	
								1717	**1717**	
								1724	**1724**	
1000	Closed-loop Encoder @ 60 ppr	Motor Conditions and Encoder Timing	**1616** 145 mA **1624** 500 mA **1717** 600 mA **1724** 750 mA	6.3"-14.8" Sealed	½"-4" std 6" custom	No	56ρm-3.5µm	38ηm-24mm	Servo .36-56 Stall 100	Servo 1.7-165 Stall 300	Servo 3.6-165 Stall 300	~~$1K~~
1100				Shorter 3.9"-18.2"	¼"-12" std 16", 18" custom	Yes Push/Pull Adaptor Option		29ηm-18mm	Servo .63-56 Stall 100			~~$1K~~
1200	Open-loop	Motor Conditions		Shortest 2.6"-15.4"			45ρm-2.8µm[2]	27ηm-17mm	1.8-56	2.1-165	4.5-165	~~$0.5K~~
								7µm-11mm	.45-56			
STEPPING MOTOR								**AM1524**				
2000	Closed-loop Encoder @ 60 ppr	Internal Hall-effect Switches	250 mA max	6.3"-14.8"	½"-4"	No	14ρm-5.1µm	56ηm-21mm	1-100			~~$1K~~
2100				Shorter 3.9"-8.4"	¼"-4"	Yes Push/Pull Adaptor Option						~~$1K~~
2200	Open-loop[3]			Shortest 3.5"-7.7"			11ρm-4.1µm	46ηm-17mm	2-100			~~$0.5K~~

[1] With 12-volt motor armature
[2] Pseudo-resolution compared to closed-loop
[3] Step counting

Housed in a tube, Linear Actuators produce linear movement by converting an electric motor's *rotation* into *translation* through a precision lead-screw and nut. Competing technologies similarly housed in a tube include –

- Pneumatic cylinder,
- Voice coil,
- Piezoelectric stack.

As usual, each technology has its own strengths and weaknesses.

MECHANICAL OVERVIEW

To produce the linear movement, a ~.2" OD Thruster protrudes on-axis from a nominal 1" OD housing in standard actuators. Depending on the model, the Thruster may be rotating or non-rotating and push up to 300 lbs.

Ironless-core brushed DC, brushless DC, or stepping motors power the actuators. **Brushed DC motors** feature –

- Precious metal brushes,
- 3-28 vdc ironless-core armature.

Stepping motors feature –

- 2-phases,
- 24-steps/rev,
- Maximum 0.25A phase current.

These high-speed motors rotate a leadscrew through a spur-gear or planetary-gear reducer. In the 1100, 1200, 2100, and 2200-series, the leadscrew itself is the thruster and protrudes through a threaded Nose Mounting. They can provide *pull* and also *push* with the **Push/Pull Adaptor** [PPA] option. In contrast, the 1000 and 2000-series have push-only plungers independent from the rotating leadscrew. Hardened Push Pads [PP#] and a protective Boot [B] for the leadscrew are available as options. In all versions, we lap the leadscrew and its mating nut for a long life of smooth, repeatable motions.

To mount, simply drill a 3/8" hole in a plate, insert the actuator, and secure with the Nose Nut (see Page 49). The shorter travel devices are specifically-designed to replace typical micrometer spindles traditionally used in precise alignment of optics and translation slides.

The actuator's compact package permits a user to nestle it into tight places without having to design a complete precision motion. For many practical applications, they are buried deep inside equipment to provide remote final alignment in difficult-to-reach locations.

MOTOR ALTERNATIVES

You can choose between the standard **stepping**, **brushed ironless-core DC**, and semi-custom **brushless DC** motors to propel the Linear Actuators. Each motor type has its strengths and weaknesses. A *Selection Guide* included in this section will help you make a choice.

ANALOG VELOCITY SERVO

Although you can drive brushed DC-motor actuators from your own electronics, we supply the SER3000 Analog Velocity Servo as well as manual and µcomputer-based controllers. The servo expects a low-current ±10 vdc velocity steering voltage from external sources such as our 1000INT, 1000MOD, CONTROL2, or CONTROL3 controllers. In spite of load variations, the servo drives the motor at a programmable constant velocity by sensing the motor's BEMF. Additional circuitry senses unusual motor conditions – moving too slow and pushing too hard – to indicate a limit-of-travel or stall conditions.

A-QUAD-B ENCODER (CLOSED-LOOP)

Both 1000/1100 and 2000/2100-series have a built-in rotary encoder directly coupled to the motor shaft. With 15PPR(Pulses per Revolution), it provides 60 counts in 4X decode. Because the motor drives the leadscrew through a gearhead, the ratio directly multiplies the 60 counts. For example, a 262:1 ratio will produce 15,720 encoder counts per revolution of the leadscrew. With a 32 TPI leadscrew, these counts produce an incremental resolution of 2 µin. The 2-phase outputs from an A-QUAD-B encoder are for direction and position information. Its magnetic construction assures high immunity to induced EMI current at either TTL or CMOS levels.

LEADSCREW PITCH

Most actuators are available with either 32.3885 or 40 TPI leadscrews. The first pitch produces an exact resolution of 0.1 µm (a common optical research standard) through the 262:1 gearhead if using 2X encoder decode.

GEARHEAD RATIO

Since the comparatively small motors have extremely high rotary velocity but low torque, we gear them down to perform useful work. The 15/5 and 16/5 gearheads are available in 18 different ratios producing an incremental resolution from 50ρm to 3µm at 4X encoder decode. The 17/5 gearhead series has 14 different ratios to produce incremental resolutions from 2ηm to 4µm. Some gearheads are available in a zero-backlash configuration that removes the 4° clearance between drive gear teeth by preloading.

ORDERING GUIDE

All Linear Actuators can be ordered with this number sequence –

Series–Travel–Motor Size–Gearhead Ratio–Leadscrew Pitch–Options

Example: 1000-05-1616-485-32-SD-V

ACTUATOR SERIES

Brushed DC
[Sensing Motor Conditions for Limit-of-Travel]

1000 ● Closed- loop ● Non-rotating thruster ● Robust, enclosed

1100 ● Closed-loop ● Shorter housing ● Rotating thruster

1200 ● Open-loop ● Shortest housing ● Rotating thruster

Stepping
[Integral Hall-effect Limit-of-Travel Sensors]

2000 ● Closed- loop ● Non-rotating thruster ● Robust, enclosed

2100 ● Closed-loop ● Shorter housing ● Rotating thruster

2200 ● Open-loop ● Shortest housing ● Rotating thruster

Brushless DC
3000[1] ● Semi-custom

[1] Contact factory

TRAVEL

1000
-05
-1
-2
-4
-6[1]

1100/1200
-025
-05
-1
-2
-4
-6
-8
-10
-12
≥**-14**[1]

2000
-05
-1
-2
-4

2100/2200
-025
-05
-1
-2
-4

MOTOR SIZE

Brushed DC
-1616
-1624
-1717
-1724

Brushless DC
-3556[1]

Stepping
-AM1524

GEARHEAD RATIO

16/5-series for brushed DC 1616 or 1624 motor

15/5-series for AM1524 stepping motor

-6.3	**-1670**
-11.8	**-3101**
-22	**-5752**
-41	**-10683**
-76	**-19813**
-141	**-36796**
-262	**-68245**
-485	**-126741**
-900	**-235067**

16/7-series for brushed DC 1717 or 1724 motors

-3.71	**-415**
-14	**-592**
-43	**-989**
-66	**-1526**
-134	**-2608**
-159	**-4356**
-246	**-5647**

LEADSCREW PITCH

-32
32.3885 TPI for actuators –
1000
1100
2000
2100

-40
40.0000 TPI for actuators –
1100
1200
2100
2200

OPTIONS

No dash designator for OPTIONS indicates STANDARD CONFIGURATION with -NB1 Nose Button and axial discharge of control cable.

-B# Boot
-B05 ½" travel
-B1 1" travel
-B2 2" travel

-NB# Nose Button
-NB1 Short radius [std]
-NB2 Long radius
-NB3 Flat

-PPA Push/Pull Adaptor

-PP# Push Pad
-PP1 Hemispherical, short-radius
-PP2 Conical, short-radius
-PP3 Hemispherical, long- radius
-PP4 Conical, long-radius
-PP5 Flat

-S#a Custom modification designator

-SD Cable Side Discharge [Axial Discharge is std]

-V Vacuum Compatibility

-ZB Zero Backlash Gearhead

-CN# Connector
-CN1 MiniDIN8P (1000, 1100, 1200, 2200)
-CN2 DA-15P (2000, 2100)
-CN3 Mono 2.5mm Phone Plug (1200)
-CN4 Tinned 18" Leads
-CN5 Ribbon & Header

HOW TO CHOOSE A GEARHEAD RATIO

Closed-Loop
While examining the Motor/Gearhead Selection Tables, pick a ratio producing less than your desired resolution. Check the maximum velocity for that gearhead. You may have to compromise your initial specifications to select the best actuator for your application. Because the motor has a fixed maximum power and encoder frequency, you must juggle Velocity against Load Capacity against Resolution.
Open-Loop
Pick a ratio producing more than your desired thrust. Check the maximum velocity. You may have to compromise your original specifications to select the best fit for Velocity and Load Capacity.

HOW TO CHOOSE A MOTOR SIZE

Brushed DC-Motor
If Load is not a significant problem, there is only one reason for selecting the 1616 motor – increased Velocity. Because the 1624 motor produces 4X torque compared to the 1616, it has 30% lower maximum velocity. When Load Capacity is important, pick the 1624 motor but expect it to move more slowly. For even higher loads, consider the 1717 and 1724 motors – the 16/7 gearhead can push up to 300 lbs.
Brushless DC-Motor – Only one model available.
Stepping Motor – Only one model available.

LOAD-CARRYING CAPACITY

The specified Load Limit is to protect the individual teeth on the spur gears. Because the leadscrew pitch is fixed (32.3885 or 40 TPI), the output drive gears see the load independent of ratio. Therefore, we limit the motor current in the Servo and thus the actuator's ability to push more than 100 or 300 lbs. Without the Servo, you may elect to push higher loads but you will sacrifice some of our mechanical warranty.

We specify two load capacity numbers – 1. @ maximum servo and 2. @ stall (limit-of-travel). The maximum servo value represents the maximum load to remain inside a constant velocity servo window such as with our SER3000 Analog Velocity Servo. Outside this window, the motor's velocity is inversely dependent on the load.

STEPPING MOTOR or DC-MOTOR?

The following table will help you choose between brushed, brushless DC motor, and a stepping motor. Although many facts are presented, often people choose one motor style over another because of personal experience or familiarity.

MOTOR PERFORMANCE COMPARISON

Category	**Stepping** (Bipolar) 2000-family		**DC** (Ironless-core) Brushless[1] Semi-Custom		Brushed 1000-family	
ELECTRONIC	Open-Loop[2]	Closed-Loop[3]	Open-loop	Closed-Loop	Open-Loop	Closed-Loop
Digital Coordinate Control	**YES**	Yes	No	Yes	No	Yes
Run-away possible?[4]	No	No	Unlikely	Unlikely	Yes	Yes
Attitude of being *In Control*?[5]	Yes	Yes	No	No	No	No
Resume *Running* after *Stall*?[6]	No	No	Yes	Yes	Yes	Yes
Sensitive to acceleration?[7]	Yes	Yes	No	No	No	No
Single-Polarity Power Supply?[8]	Yes	Yes	Yes	Yes	No	No
Complex Drive Electronics?[9]	Yes	Yes	Some	Some	No	No
MECHANICAL						
Acoustic Noise?[10]	Yes	Yes	Some	Some	No	No
Excessive Vibration?[11]	Yes	Yes	No	No	No	No
Motor runs hot?[12]	Yes	Yes	No	No	No	No
Brushes to wear-out?[13]	No	No	No	No	Yes	Yes
High inertia?[14]	Yes	Yes	Yes	Yes	No	No
Inaccuracy under load?[15]	Yes	Yes	No	No	No	No

1. **Brushless** DC-motors are only available in semi-custom 2" OD housings for high-thrust applications.
2. **Open-Loop** control of a stepping motor requires counting the step commands to control the position. If you loose step-synchronization, the controller will be unaware of this condition unless some expected external event is also missing.
3. **Closed-Loop** control of a stepping motor means that an A-QUAD-B position encoding device is somewhere in the motion subsystem. Although you issue individual step commands, you determine the final position by the encoder, independent of the number of steps. Even with loss of step synchronization, the encoder information is accurate.

4 Run-away?

In contrast to easily-controlled brushed DC motors, stepping motors and brushless DC-motors require complex switching of current flow through the motor windings. Therefore, failure in a servo, amplifier, or power-supply can falsely move the brushed DC motor – causing the motor to run-away! While the DC motor's tendency is to *move*, the stepping motor's tendency is to *not move*. Although a simple battery will move a brushed DC motor, only complex electronics will move a stepping motor.

5 Attitude of Being IN CONTROL?

Each step is the result of a deliberate electronic event. In contrast, the brushed DC motor only needs a voltage source to run. In a closed-loop environment, instead of thinking *GO TO HERE*, you ask a DC motor, *WHERE ARE YOU*? In DC controllers, the encoder counts maintain either a hardware or software position counter. Stepping controllers issue timed pulses to a driver that produces the complex switching to move the motor.

6 Resume Running after Stall?

A stepping motor can lose step-synchronism easily if the load increases beyond the operating window for the current velocity or acceleration. If the time is long enough, the motor will stall until the motion sequence starts again. Even if it is operating with an encoder in closed-loop fashion, the motor will stall. The controller must handle this error condition and restart the motion toward the final coordinate.

In comparison, the DC motor – brushless or brushed – ***will continue to try to move in the face of adversity***. Although it may slow down, it will resume running normally after removing the offending load. However, in a closed-loop environment with digital velocity servoing, the controller may sense a following error and terminate the motion.

7 Sensitive to Acceleration?

Stepping motors will lose step-synchronization if accelerated or decelerated too fast. Taking the *next* step *too early* or *too late causes this error and* results in loss of step synchronism – it may even run backwards! If the load varies, it is difficult to exactly find the correct acceleration to guaranty faultless stepping. One common approach is to accelerate much more slowly to assure not losing synchronism. Although you don't lose position when the motor stalls in closed-loop environment, it is inconvenient to restart the motion.

8 Single-Polarity Power Supply?

We use balanced-bridge analog velocity servos with our DC motors to achieve a smooth, quick-response movement. In contrast, some pulse-width modulated (PWM) servos may create audio noise, mechanical vibration, and cogging at low velocities. The balanced-bridge servo by necessity has a bipolar power source (±15vdc-).

On the other hand, both the brushed DC-motor and stepping motor operate from unipolar supplies.

9 Complex Drive Electronics?

Although brushed DC motors can run from a battery, brushless DC and stepping motors require more elaborate electronic controllers. Eventually, both motors often have complex controllers due to all the collateral events they are controlling – limit handling and encoder decoding.

10 Acoustic Noise?
11 Excessive Vibration?

The stepper's action is violent – especially for full steps – the magnitude of the switched electrical current is independent of motor velocity! This jolt produces both audio noise and mechanical vibration that is especially noticeable at lower velocities. However, the DC brushed and brushless motors feature seamless transitions from winding to winding. Except for vibration from bearings and air currents, these motors are noise and vibration free!

Fortunately, microstepping reduces the current differential being switched and the acoustic noise. Due to the motor's construction, we recommend limiting microstepping to 4X – unfortunately, this is still not sufficient to completely illuminate noise and vibration.

12 Motor runs hot?

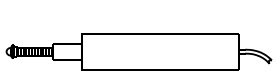
A stepping motor is often fully-powered all the time to retain its maximum holding torque. If the system friction is high enough, holding current can be substantially lowered. For example, we recommend reducing the current to 100mA from a running 250mA when stopped. In either case, this continuous current makes the stepping motor hotter than equivalent DC motors. Because the motor gets hot, the linear actuators should be in contact with a heat conducting element such as a thick metal plate. Without adequate heat conduction, it is possible to overheat and destroy the motor windings.

13 Brushes to wear-out?

Obviously, stepping and brushless DC motors do not have brushes to wear out – this is one of their primary strengths. In contrast, even the precious metal brushes of normal DC motors eventually wear out. The only question is: how long do they last? While the motor manufacturer conservatively specifies the brushes for 1000 hours at maximum conditions, we anticipate 2000-5000 hours. In stepping and brushless DC motors, the bearings should last for 50,000 hours.

14 High inertia?

Since they have no moving magnets, only brushed, ironless-core DC motors can exhibit ultra-low rotor inertia. In contrast, both the stepping and brushless DC motors have moving permanent magnets. This increased mass invariably results in slower starts and stops when compared to ironless-core DC motors with identical magnetic materials. However, the effects of higher inertia are effectively negated by high-strength samarium-cobalt rotor magnets in the stepping motor.



15 Inaccuracy under load?

In unloaded condition, stepping motor's accuracy is ±3% of full step or ±27 arc minutes. Under load, accuracy is further decreased an arc minute for every load change equivalent to 1% of the motor's rated torque. Since the stepper holds position by balanced magnetic fields – additional force always causes position distortion. In contrast, the closed-loop DC motor has no errors introduced by loading variations. *However, the accuracy of both motors is equivalent in a closed-loop environment.*

SELECTION GUIDE

COMPARATIVE FEATURES

Stepping

1. Long life due to absence of brushes;
2. Vibrates and noisy in full or half-step operation – *4X maximum microstep recommended;*
3. Direct open-loop control – *Move another step;*
4. Less-expensive position control;
5. Larger size required to assure accurate open-loop performance;
6. Higher inertia from rotating permanent magnets results in slower *Start* and *Stop* performance;
7. Numerous, but complex low-cost controllers available;
8. Possible loss of step-synchronism causing *Stall;*
9. Runs hot, even at rest;
10. Unipolar power supply;
11. No EMI from arcing nor particulate contamination from brushes;
12. Open-loop microstep inaccuracy under varying loads;
13. *Thinks* digital.

Brushed DC

1. Gold and silver brush/commutator give 2000-5000 hours lifetime;
2. Ultra-smooth and quiet in all modes of operation
3. Indirect control – *Where are you?;*
4. Position control requires encoder/resolver;
5. Smaller size since it never looses step-synchronization;
6. Low inertia from ironless-core results in rapid *Start* and *Stop* performance;
7. Fewer, but simple higher-cost controllers;
8. In closed-loop environment, always tries to mov without loss of information;
9. No electrical power consumption at rest;
10. Bipolar power supply;
11. Minimal arcing and zero contamination due to arc suppression and fine metal brushes;
12. Accuracy independent of load;
13. *Thinks* analog.

RECOMMENDATIONS

Condition	Brushed DC 1000-family	Stepping 2000-family	BLDC[1] 3000-series
1. Equipment sensitive to vibration – optics, interferometry, pattern generation.	✓	–	✓
2. Long life at maximum conditions.	–	✓	✓
3. Vacuum environment.	✓	–	✓
4. Ultra-fast starting and stopping response.	✓	–	–
5. Zero EMI.	–	✓	✓
6. Low thermal emissions.	✓	–	✓
7. Interface to standard board level controllers for table-top PCs.	–	✓	–
8. Low electrical power consumption.	✓	–	✓
9. Low acoustical noise.	✓	–	✓
10. *Open-loop position control.*	–	✓	–
11. Run-away protection from secondary component failure.	–	✓	✓
12. High accuracy under load.	✓	–	✓
13. Repeatable HOME sensor.[2]	–	✓	✓

[1] Brushless DC-motor only available in semi-custom, high-thrust, 2" OD Linear Actuator versio

[2] Check availability of built-in Hall-effect Limit-of-Travel sensors for 1000-fami

LEADSCREW ACCURACY

A Linear Actuator's absolute accuracy is first a function of the leadscrew's pitch accuracy. Even though the gearhead/encoder combination may produce a large number of counts per leadscrew revolution, absolute position directly relates to pitch accuracy.

The leadscrew is fabricated by single-point cutting on a CNC lathe in a temperature regulated environment. It is lapped to produce a fine surface and mated to its Nose Mounting or Nut. However, this lapping does little to compensate for pitch errors.

We calibrate the lathe with a laser and control its leadscrew through a look-up table.
Because of the prohibitive cost of a more accurate leadscrew, one method for improving absolute accuracy is to use a computer look-up table. With a look-up table, you must have a repeatable starting point – a HOME point. Fortunately, the 2000-family has built-in Hall-effect sensors for both the Forward and Reverse limit. You can use either sensor as the HOME sensor, repeatable to at least 10 µin (0.25 µm).

Error analysis by **laser interferometer** shows that our leadscrews have maximum peak-to-peak pitch errors ranging from ±0.5 µm to ±5 µm over 4" travel.

Another accuracy improvement method is a collateral A-QUAD-B external linear encoder such as a glass scale.

TS Products will supply leadscrew calibration by laser interferometer as an option.

RESOLUTION

Resolution is the smallest incremental distance represented by one step or encoder count. Resolution does not relate to absolute accuracy. However, during leadscrew calibration, the resolution governs the sample interval of the data.

BACKLASH

Backlash is present in most all mechanical systems, although it might be too small to be perceived. We define backlash as the absence of physical movement when the direction is first reversed. Clearances between moving internal parts cause the backlash but also permit smooth operation. There is no resultant motion until all the tolerances in the mechanical system have been taken out and the force is again applied to the output.

Common methods to remove or reduce backlash when using Linear Actuators –

1. Relatively-high unidirectional load
   - Spring-return of translation stages
   - Gravity
2. Zero-backlash gearheads (-ZB Option)
3. Motion-control programming that always approaches the final coordinate in the same direction.
4. Motion-control programming that compensates for known backlash every time there's a switch in direction.

ZERO-BACKLASH GEARHEAD

80% of backlash in the in-line linear actuators is caused by the clearance of the teeth in the 15/5 and 16/5 gearhead's output drive gear. The -ZB option removes this major contributor.

The Zero Backlash Gearhead contains two parallel stacks of spur gears in one package with a common attachment to both the output and motor drive gear. Prior to joining with the motor, one gear stack is advanced until all the tooth clearance at the output gear is consumed. Now, it is joined to the motor's drive gear and the gearhead-generated backlash is canceled. This preloading increases friction and diminishes lifetime slightly.

BACKLASH	
Gearhead Style	
Normal	10 µm ± 1 µm
Zero-Backlash	2 µm ± 1 µm

BACKLASH CONSTANT?

While backlash is never a constant because of eccentricities in the individual gears as well as irregularities in guidance slots, the following table is the expected nominal backlash. The best method for determining maximum backlash is to perform a physical experiment.

BACKLASH RESPONSE KNEE

At the relatively fine dimensions of linear actuators with high gear ratios, the knee of the response curve is not sharp. As the backlash begins to be picked-up, the physical movement for each resolution element is less than expected. Eventually, the movement matches the resolution and the actuator responds linearly again.

EXPECTED BACKLASH

GEARHEAD RATIO	1100-series (60-count Encoder)			2200-series (24 full-steps/rev)		
	Distance per Count	EQUIVALENT COUNTS		Distance per Step	EQUIVALENT STEPS	
		Normal	Zero-Backlash		Normal	Zero-Backlash
6.3:1	2.0 µm	5	1	4.1 µm	2	0
11.8:1 ▾ 262:1 ▾ 3101:1[1]	1.1 µm ▾ 0.05 ▾ 4.1 ηm	9 ▾ 200 ▾ 2439	2 ▾ 40 ▾ 488	2.2 µm ▾ 76 ηm ▾ 8.4 ηm	5 ▾ 132 ▾ 1193	1 ▾ 26 ▾ 239

[1] Zero-backlash Gearhead Option is only available up through the 3101:1 gear ratio.

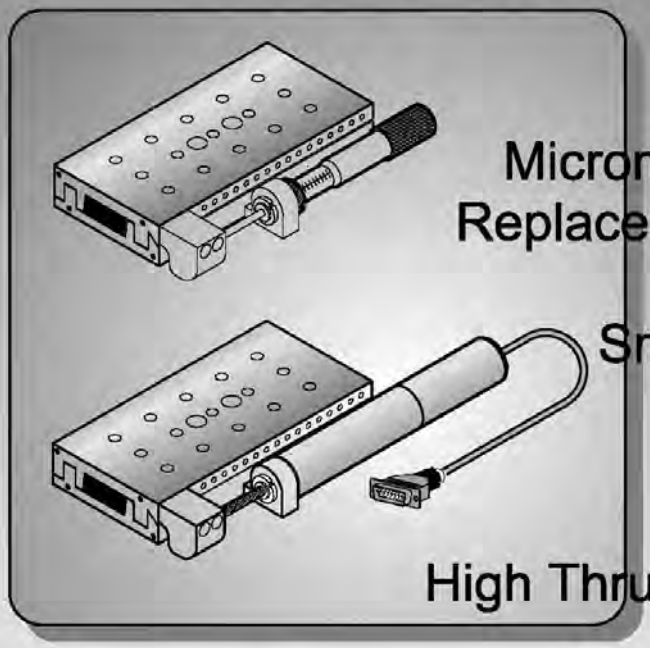
SIDELOAD

Sideload on the extended Thruster will increase internal friction and reduce available thrust dramatically. When rotating a tangent arm with a linear actuator, sideload becomes a significant factor influencing the thrusting force. As a rule of thumb, limit the sideload to a maximum of 5 lbs.

PRECISION
MINIATURE

Ironless-Core DC-Motor LINEAR ACTUATORS

1000-Family



Micrometer Replacement

Smooth

Quiet

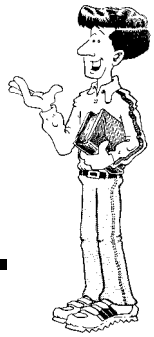
High Thrust/Weight Ratio

Diamond Motion, Inc.
P.O. Box 1225
Port Angeles, WA 98362-0227 USA
360-417-9791 Fax 360-417-9794

SECTION CONTENTS

1000-family

1000-series 10
1100-series 16
1200-series 20



1000-series Linear Actuators

These high-quality actuators directly replace micrometer heads in micro-motion applications with a typical resolution of 0.05µm. With built-in magnetic A-QUAD-B position encoder for closed-loop positing applications, the 1000-series are available in 32 resolution/velocity variations, 4 travels, and 3 load categories. Its principal feature is a non-rotating thruster that pushes against an external return force.

Formed in a 1"OD housing, this actuator is rugged enough to withstand an accidental drop on the floor. Quiet and sealed from external moisture and dust contamination, the 1000-series can perform directly exposed to harsh weather.

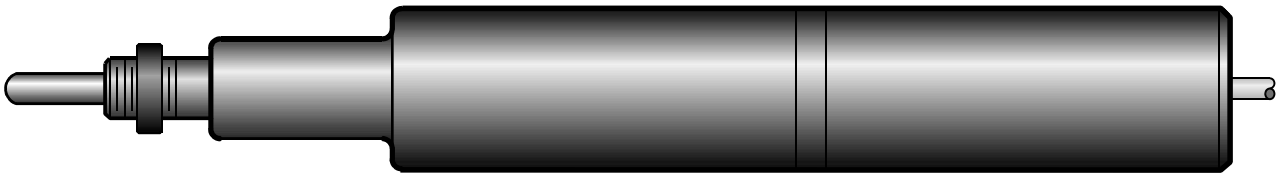
The 1000-series can be operated from either your controller/servo or from our SER3000-series of Analog Velocity Servos. In its normal configuration, the 18" cable from this actuator is terminated in a MiniDIN8P connector. For vacuum environment, all lubricants are space-qualified.

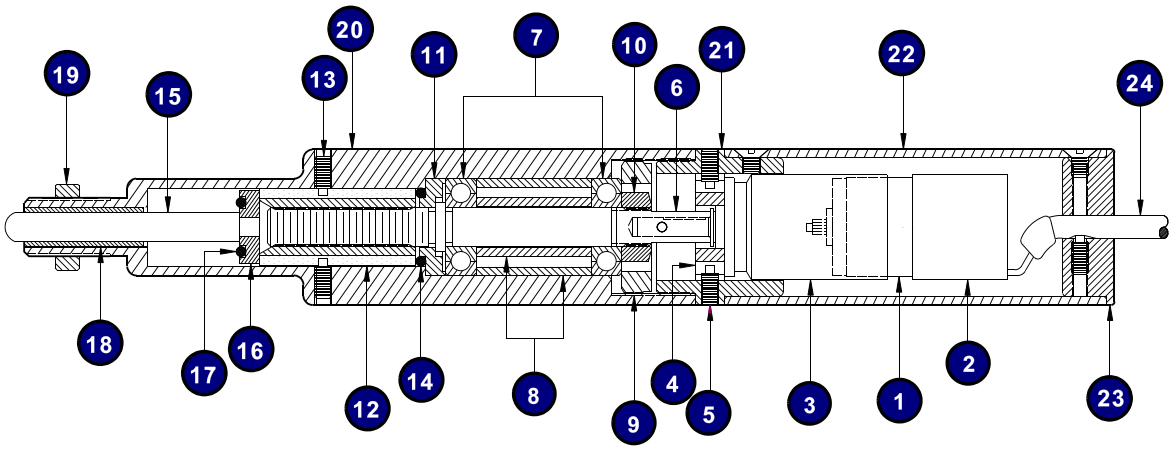
Major Features

- Non-rotating thruster
- Built-in position encoder
- Travels of ½", 1", 2", 4"
- Thrusts up to 300 lbs.
- Maximum velocity up to 18 mm/sec
- Resolutions down to 2.2 ηin (56 ρm)
- Expected minimum absolute accuracy = 2 µm/in
- Internal limit-of-travel/torque sensing through Analog Velocity Servo
- Vacuum-compatibility option
- Axial or side cable discharge

Typical Customizing

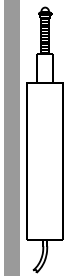
- Thruster length variation
- Omit position encoder
- Cable length variation
- Increased thrust capacity
- Adjustable thrust limit
- Leadscrew error calibration





MECHANICAL PARTS DESCRIPTION

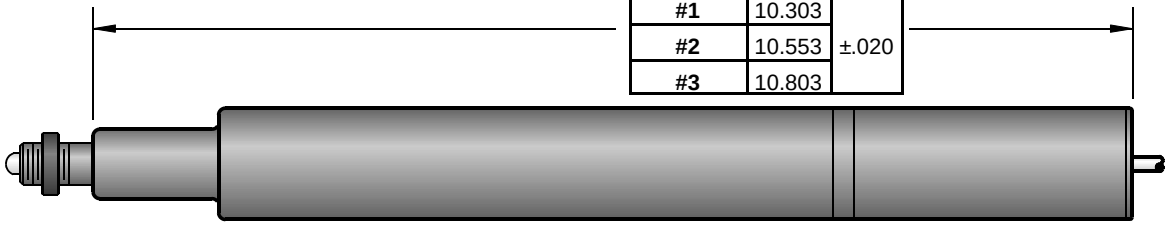
1 **MOTOR**	• MicroMo 1616, 1624, 1717, or 1724 motor with armature voltage ranging from 3-24 volts (17,000 RPM maximum velocity).
2 **ENCODER**	• MicroMo HE15 Magnetic Encoder with 60 counts at 4X decode provides position information.
3 **GEARHEAD**	• MicroMo 16/5 or 16/7 Gearhead with ratios from 3.71:1 to 235,067:1 depending on space available – see charts. • Attached to gearhead to prevent rotation.
4 **HUB**	• Prevents HUB from rotating.
5 **DOG-POINT SET SCREWS** 6 **DRIVESHAFT**	• Stationary, precision-ground stainless-steel with 32.3885 TPI pitch converts rotary motion into linear movement of Drive Nut. Bonded to gearhead output shaft with Loctite adhesive rated at -65°F to 300°F temperature range.
7 **BEARINGS**	• Precision stainless-steel bearings promote exceptionally-smooth motion. • Locks bearings into position.
8 **BEARING SPACERS**	• Supports bearing outer race.
9 **OUTER RACE NUT**	• Supports bearing inner race.
10 **INNER RACE NUT** 11 **BEARING SEAT**	• Contacts outer bearing race and supports Reverse Stop Cushion.
12 **DRIVENUT**	• Phosphor-bronze nut moves linearly as Driveshaft rotates to produce motion. • Rides in mating slot in Drivenut to prevent rotation during linear motion.
13 **DOG-POINT SET SCREWS** 14 **REVERSE STOP CUSHION**	• Rubber O-ring provides soft stop for Drivenut at Reverse End-of-Travel.
15 **PUSH ROD**	• Non-rotating stainless-steel rod provides linear thrust to object being pushed – polished; hardened by heat-treatment; 0.1875 spherical dia tip.
16 **FORWARD STOP** 17 **FORWARD STOP CUSHION**	• Force-fit onto Push Rod, provides Forward Limit-of-Travel. • Elastomer cushion provides soft FORWARD Limit-of-Travel.
18 **NOSE BEARING**	• Precision cylinder bearing is force-fit to Housing. Lapped to Push Rod for smooth, low-jitter, thrusting movement.
19 **MOUNTING NUT**	• 0.55" OD secures actuator to mounting plate. ID 3/8-40 UNC.
20 **HOUSING**	• <1" OD, black anodized tube. Vacuum-compatible Housing is unanodized. • Joins Motor Housing to Housing.
21 **COUPLER**	• Covers Motor/Gearhead/Encoder.
22 **MOTOR HOUSING**	• Closes Motor Housing and provides strain-relief for cable.
23 **END CAP**	
24 **ACTUATOR CABLE**	• 1/8" OD cable with 7 conductors.



MOTOR HOUSING	DIM	TOL
#1	14.303	±.020
#2	14.553	
#3	14.803	

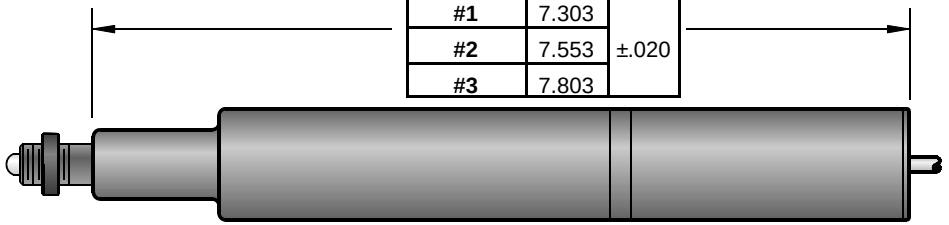
4" TRAVEL

MOTOR HOUSING	DIM	TOL
#1	10.303	±.020
#2	10.553	
#3	10.803	



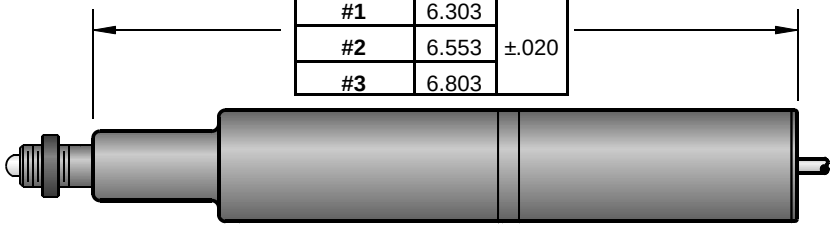
2" TRAVEL

MOTOR HOUSING	DIM	TOL
#1	7.303	±.020
#2	7.553	
#3	7.803	



1" TRAVEL

MOTOR HOUSING	DIM	TOL
#1	6.303	±.020
#2	6.553	
#3	6.803	

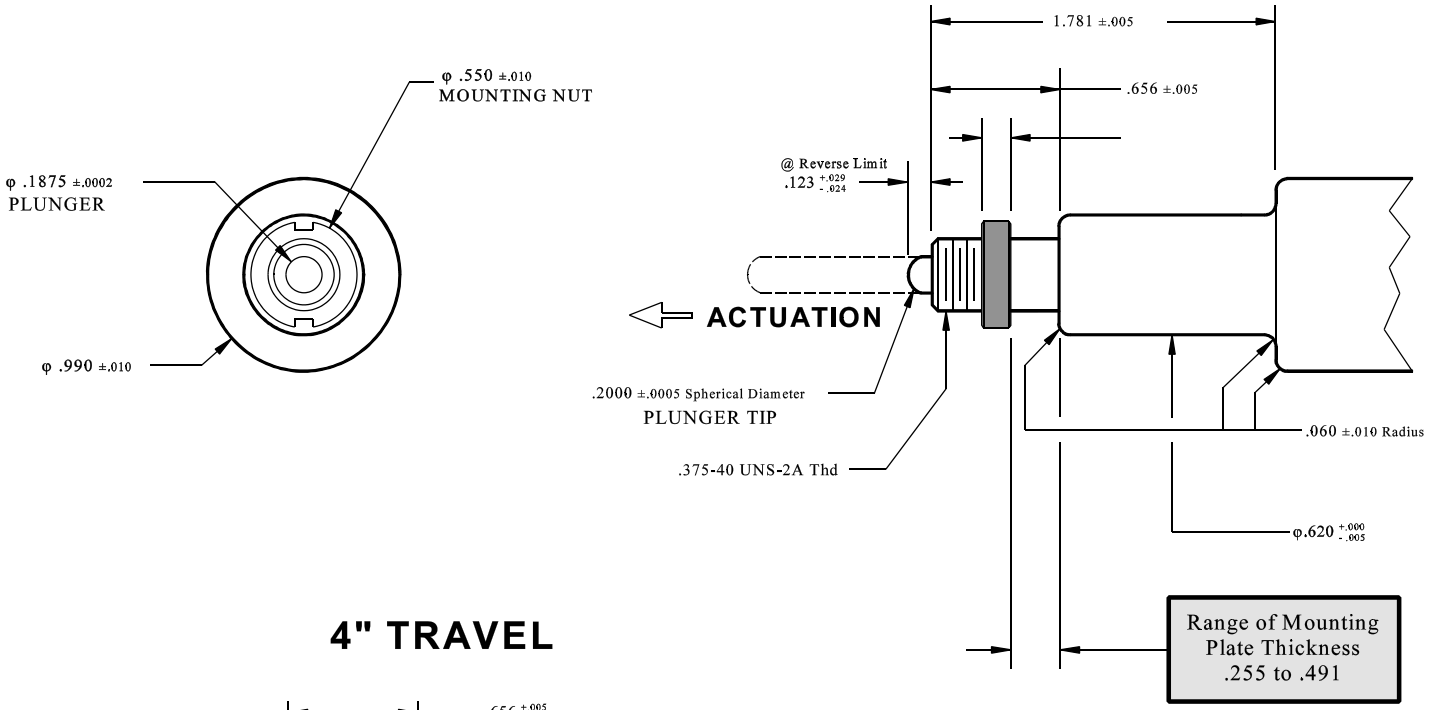


0.5" TRAVEL

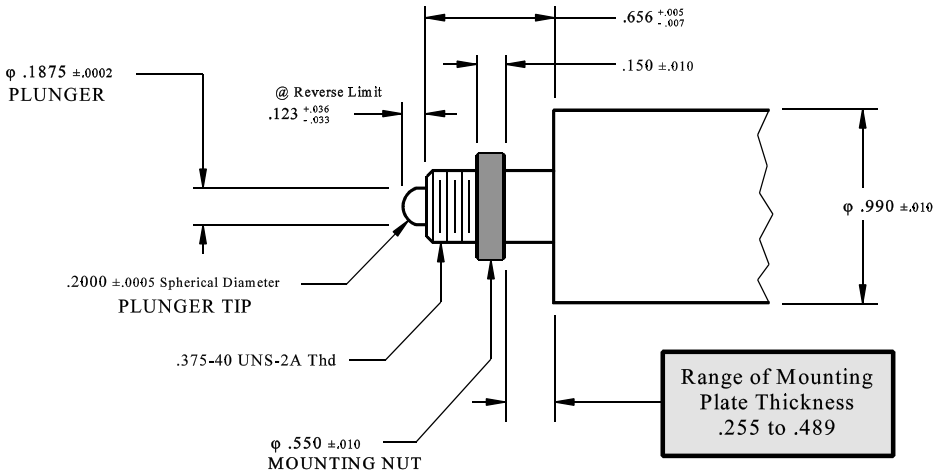
AVAILABLE GEAR RATIOS	
16/5	**17/5**
6.3:1	3.71:1
11.8:1	14:1
22:1	43:1
41:1	159:1
76:1	246:1
141:1	415:1
262:1	592:1
485:1	989:1
900:1	1,526:1
1,670:1	2,608:1
3,101:1	4,365:1
5,752:1	5,647:1
10,683:1	
19,813:1	
36,796:1	
68,2451	
126,741:1	
235,067:1	

PERMITTED MOTOR/GEARHEAD COMBINATIONS				
MOTOR SIZE	**1616**	**1624**	**1717**	**1724**
MOTOR HOUSING	**HIGHEST POSSIBLE GEAR RATIO**			
#1	485:1	11.8:1	Contact Factory	
#2	19,813:1	141:1		
#3	235,067:1	5,752:1		

0.5" TO 1" TRAVEL



4" TRAVEL



NOMINAL TRAVEL	ACTUAL TRAVEL Prior to Cushion Compression	AVERAGE WEIGHT (oz.)
0.5"	0.569 +.022 -.027	8.2
1"	1.069 +.022 -.027	9.2
2"	2.069 +.022 -.027	12.1
4"	4.069 +.022 -.027	22.4

MOTOR/GEARHEAD SELECTION TABLE

1616 or 1624 Motors & 16/5 Gearheads with 4X Encoder Multiplier

1000/1100-Series Linear Actuator

Leadscrew = 32.38853 TPI

GEARHEAD RATIO	RESOLUTION[1]	VELOCITY[2] units/sec		MAXIMUM LOAD[3] (lbs)			
		1616 Motor	1624 Motor	1616 Motor		1624 Motor	
				Servo[4]	Stall[5]	Servo[4]	Stall[5]
6.3 [6.39683]	2.04 µm *80.4* µin	.69-14 mm *27-550* mils	.53-11 mm *21-420* mils	.56 .25kgm	.97 .44kgm	2.2 1.kgm	3.9 1.8kgm
11.8 [11.86420]	1.10 *43.4*	.37-7.5 *15-290*	.29-5.7 *11-230*	1.0 .45kgm	1.8 .82kgm	4.2 1.9kgm	7.2 3.3kgm
22 [22.03351]	593 ηm *23.4* µin	.20-4.0 *7.9-160*	.15-3.1 *6.1-120*	1.7 .77kgm	3.0 1.4kgm	7.0 3.2kgm	12 5.5kgm
41 [40.86557]	320 *12.6*	.11-2.2 *4.3-86*	.08-1.7 *3.3-65*	3.2 1.5kgm	5.6 2.5kgm	13 5.9kgm	22 10kgm
76 [75.89319]	172 *6.78*	.059-1.2 *2.3-46*	45-900 *1.8-35*	5.4 2.4kgm	9.4 4.3kgm	22 10kgm	38 17kgm
141 [140.75917]	92.9 *3.66*	32-630 µm *1.2-25* mils	24-480 µm *.95-19* mils	10 4.5kgm	17 7.7kgm	40 18kgm	70 32kgm
262 [261.40989]	50.0 *1.97*	17-340 *.67-13*	13-260 *.51-10*	17 7.7kgm	29 13kgm	56[6] [67]	100[6] [120]
485 [484.83713]	27.0 *1.06*	9.2-180 *.36-7.2*	7.0-140 *.28-5.5*	31 14kgm	54 24kgm	56 26kgm	100 45kgm
900 [900.41181]	14.5 ηm *571* ηin	4.9-99 *.19-3.9*	3.8-75 *.15-3.0*	52 24kgm	90 41kgm	56	100
1670 [1669.99451]	7.83 *308*	2.7-53 *.10-2.1*	2.0-41 *.080-1.6*	56[6] [96]	100[6] [170]	56	100
3101 [3101.41837]	4.21 *166*	1.4-29 *.056-1.1*	1.1-22 µm *43-860* µin	56 26kgm	100 45kgm	56	100
5752 [5752.20313]	2.27 *89.5*	.77-15 µm *30-610* µin	.59-12 *23-470*	56	100	56	100
10683 [10682.66295]	1.22 *48.2*	.42-8.3 *16-330*	.32-6.4 *13-250*	56	100	56	100
19813 [19813.14453]	660 ρm *26.0* ηin	.22-4.5 *8.8-180*	.17-3.4 *6.7-140*	56	100	56	100
36796 [36795.83984]	355 *14.0*	.12-2.4 *4.8-95*	.092-1.8 *3.6-73*	56	100	56	100
68245 [68245.27344]	192 *7.54*	.065-1.3 *2.6-51*	.050-1.0 *2.0-39*	56	100	56	100
126741 [126741.22210]	103 *4.06*	35-700 ηm *1.4-28* µin	27-540 ηm *1.0-21* µin	56	100	56	100
235067 [235067.04688]	55.6 *2.19*	19-380 *.74-15*	15-290 *.57-11*	56	100	56	100

1 At 60 *A-QUAD-B* encoder counts per revolution.

2 Typical 20:1 velocity range for *continuous-style* motion.

3 @ max velocity (50% No-Load Velocity). Typical variation of maximum load for 1000-series is ±30%. 1100-Series is ±35%. Suggested minimum load is 7 lbs or 50% of maximum for optimal operation.

4 While still inside a typical velocity servo window.

5 @ velocity = 0 (STALL).

6 Maximum thrust at STALL limited to 100 lbs to protect gearhead from damage. Maximum thrust at maximum velocity still within Servo Window is 56% of STALL thrust. Limitation by motor current reduction.

MOTOR/GEARHEAD SELECTION TABLE

1717 or 1724 Motors & 16/7 Gearheads with 4X Encoder Multiplier

NOTE Contact factory for limitations on particular combinations of motor, gearhead ratio, and travel.

1000/1100-Series Linear Actuator

Leadscrew = 32.38853 TPI

GEARHEAD RATIO	RESOLUTION[1]	VELOCITY[2] units/sec		MAXIMUM LOAD[3] (lbs)			
		1717 Motor	1724 Motor	1716 Motor		1724 Motor	
				Servo[4]	Stall[5]	Servo[4]	Stall[5]
3.71 [ ]	3.52 µm *139* µin	.92-18 mm *36-720* mils	.56-11 mm 22-440 mils	1.7 .77kgm	2.9 1.3kgm	3.6 1.6kgm	6.2 2.8kgm
14 [13.7959]	947 ηm *37.3* µin	.25-4.9 *9.7-194*	.15-3.0 *6.0-120*	5.6 2.5kgm	9.7 4.4gm	12 5.4kgm	21 9.5kgm
43 [42.9206]	305 *12.0*	.079-1.6 *3.1-62*	48-970 µm *1.9-38* mils	15 6.8kgm	26 12kgm	32 15kgm	56 25kgm
66 [66.2204]	197 *7.77*	.051-1.0 *2.0-40*	32-630 *1.2-25*	23 10kgm	41 19kgm	50 23kgm	87 39kgm
134 [133.5309]	97.9 *3.85*	25-510 µm *1.0-20* mils	16-310 *.62-12*	41 19kgm	70 32kgm	86 39kgm	150 68kgm
159 [159.4195]	82.0 *3.23*	21-430 *.84-17*	13-260 *.52-10*	48 22kgm	84 38kgm	100 45kgm	180 82kgm
246 [245.9615]	53.1 *2.09*	14-280 *.54-11*	8.5-170 *.33-6.7*	75 34kgm	130 59kgm	160 73kgm	280 130kgm
415 [415.4294]	31.5 *1.24*	8.2-160 *.32-6.4*	5.0-100 *.20-4.0*	120 54kgm	200 91kgm	165[6] [250]	300[6] [430]
592 [592.1296]	22.1 ηm *869* ηin	5.7-110 *.23-4.5*	3.5-71 *.14-2.8*	160 73kgm	290 130kgm	165 73kgm	300 140kgm
989 [988.8914]	13.2 *520*	3.4-69 *.14-2.7*	2.1-42 *.83-1.7*	165[6] [280]	300[6] [480]	165	300
1526 [1525.7182]	8.57 *337*	2.2-45 *.087-1.8*	1.4-27 *.51-1.1*	165 75kgm	300 140kgm	165	300
2608 [ ]	5.01 *197*	1.3-26 *.051-1.0*	.80-16 µm *32-630* µin	165	300	165	300
4365 [ ]	2.99 *118*	.78-16 µm *31-610* µin	.48-9.6 *19-380*	165	300	165	300
5647 [ ]	2.31 *91.1*	.60-12 *24-470*	.37-7.4 *15-290*	165	300	165	300

1 At 60 *A-QUAD-B* encoder counts per revolution.
2 Typical 20:1 velocity range for *continuous-style* motion.
3 @ max velocity (50% No-Load Velocity). Typical variation of maximum load for 1000-series is ±30%. 1100-Series is ±35%. Suggested minimum load is 7 lbs or 50% of maximum for optimal operation.
4 While still inside a typical velocity servo window.
5 @ velocity = 0 (STALL).
6 Maximum thrust limited to 300 lbs to protect gearhead teeth from damage. Maximum thrust at maximum velocity still with Servo Window is 56% of STALL thrust. Limitation by motor current reduction.

1100-series Linear Actuators

Although these actuators have a built-in A-QUAD-B position encoder for closed-loop operation, they are much shorter than the 1000-series because the rotating leadscrew is also the thruster. A typical length reduction is 2.28" for the 0.5" travel. Two guiding slots on opposite sides of the housing prevent the motor from rotating as the leadscrew is rotated. Marked keys in these slots also serve as a coarse indicator of position.

A shaped and polished Nose Button provides a precise contact point as well as a Reverse mechanical stop. The Forward mechanical stop is provided by an elastomer cushion inside the housing connected directly to the leadscrew. The keys in the guiding slots do not provide any ends-of-travel. In this way, the severe mechanical forces from running into the ends-of-travel are prevented from reaching the gearhead and motor.

For pulling applications, a [-PPA] Push/Pull Adaptor option replaces the Nose Button.

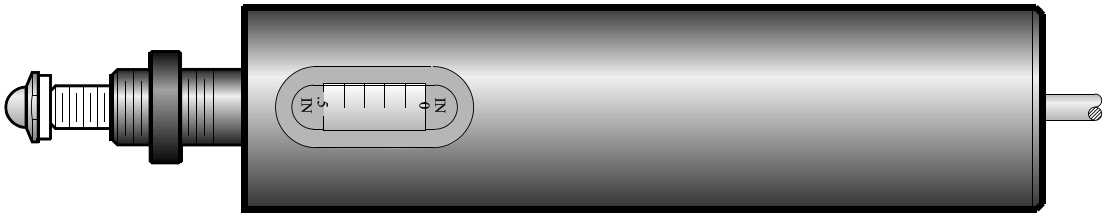
The 1100-series can be operated from either your controller/servo or from our SER3000-series of Analog Velocity Servos. In its normal configuration, the 18" cable from this actuator is terminated in a MiniDIN8P connector. For vacuum environment, all lubricants are space-qualified.

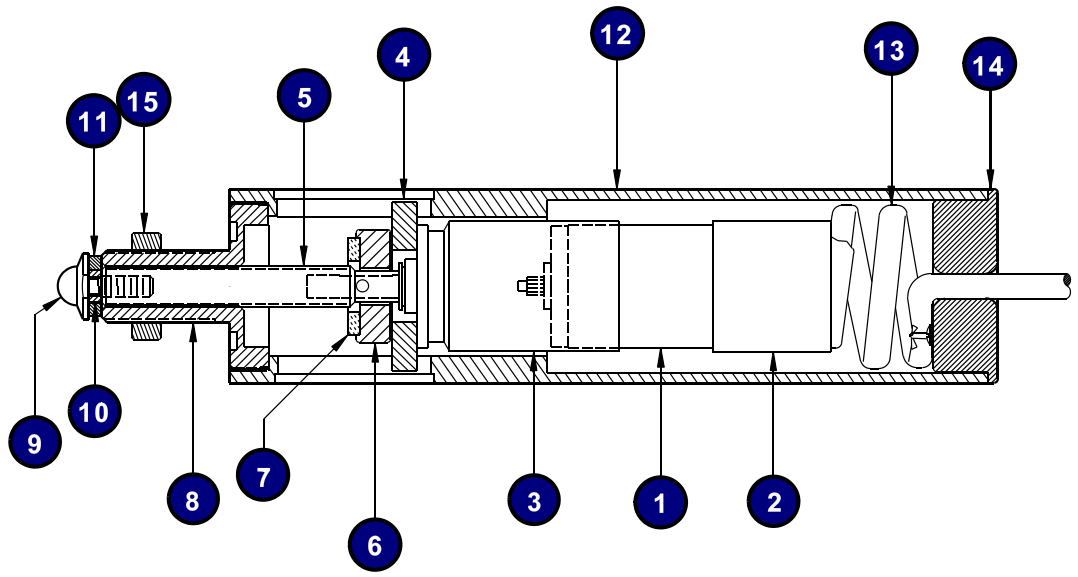
Major Features

- Short housing length
- Built-in position encoder
- Travels of ¼", ½", 1", 2", 4", 6", 8", 10", 12" [Custom = 16", 18"]
- Thrusts up to 300 lbs.
- Maximum velocity up to 18 mm/sec
- Resolutions down to 2.2 ηin (56 ρm)
- Expected minimum absolute accuracy = 2 µm/in
- Internal limit-of-travel/torque sensing through optional SER3000 Analog Velocity Servo
- Vacuum-compatibility option
- Axial or side cable discharge

Typical Customizing

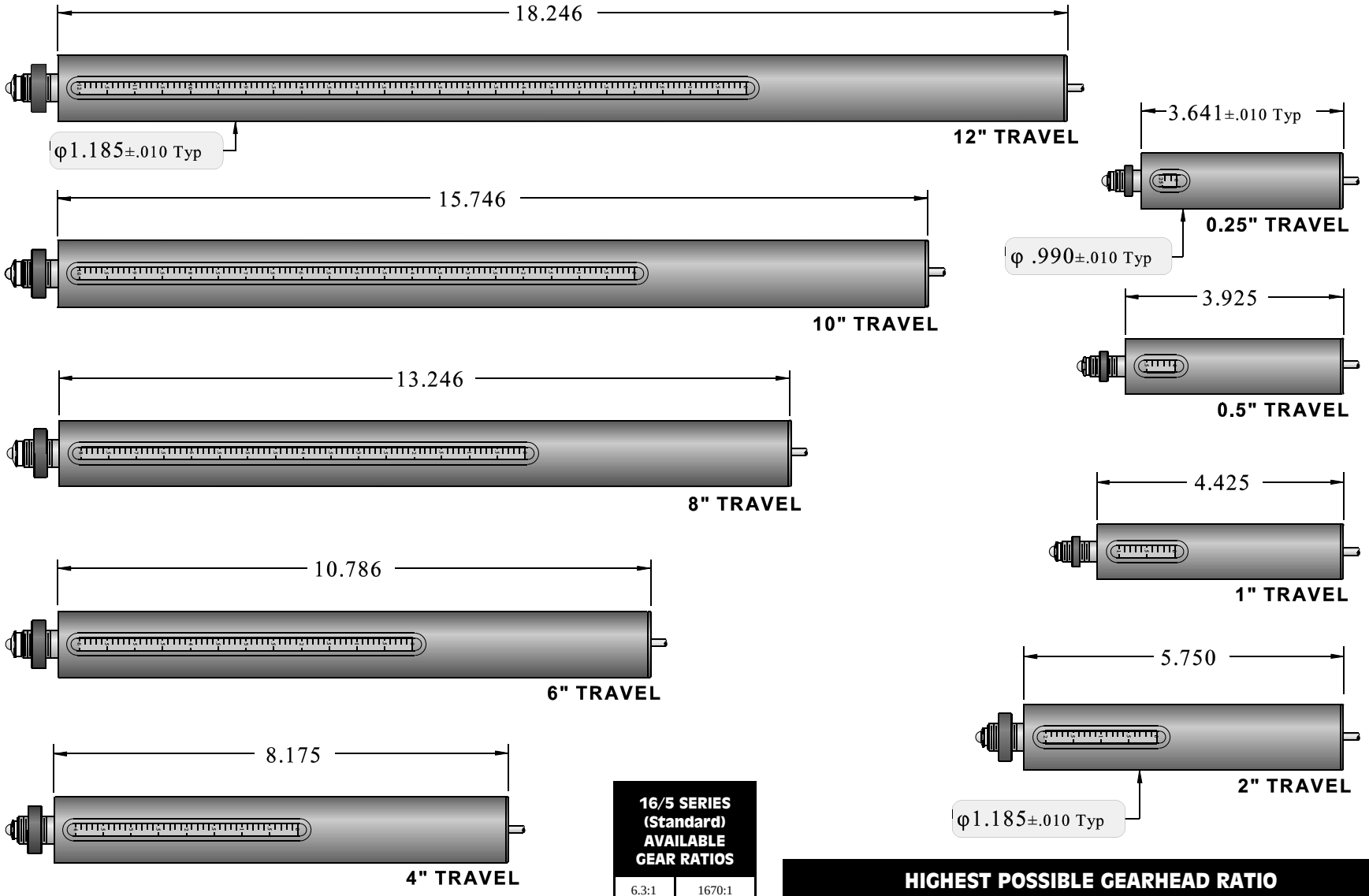
- Shorter housing
- Non-standard travels, such as 0.6"
- Thruster length variation
- Omit position encoder
- Cable length variation
- Increased thrust capacity
- Adjustable thrust limit
- Leadscrew error calibration
- Custom Nose Button





MECHANICAL PARTS DESCRIPTION

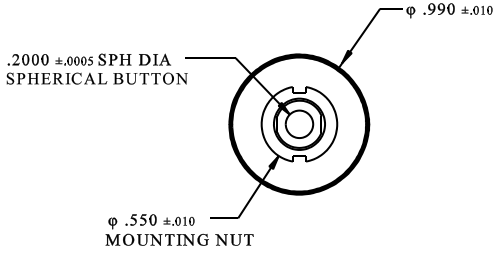
1	**MOTOR**	• MicroMo 1616, 1624, 1717, or 1724 motor with armature voltage ranging from 3-24 volts (17,000 RPM maximum velocity).
2	**ENCODER**	• MicroMo HE15 Magnetic Encoder with 60 counts at 4X decode provides position information.
3	**GEARHEAD**	• MicroMo 16/5 or 16/7 Gearhead with ratios from 3.71:1 to 235,067:1 depending on space available – see charts.
4	**KEY**	• Double-tabbed key holds the gear-head from rotating and prevents choking sideloads created by single-tabbed designs.
5	**DRIVE SHAFT**	• Precision-rolled/ground stainless-steel with either 32.3885 TPI or 40.0000 TPI pitch converts rotary motion into linear movement – bonded onto gearhead output shaft with Loctite adhesive rated at -65°F to 300°F temperature range.
6	**FORWARD STOP** [Stop Shaft Extension]	• Rigidly fixed on the Driveshaft, this rotating piece stops all forward motion when it touches the Nose Mounting.
7	**FORWARD STOP CUSHION**	• Teflon or rubber donut produces smooth, soft stops.
8	**NOSE MOUNTING**	• Stationary phosphor-bronze nut for Driveshaft. Outer mounting threads are ⅜-40 UNC.
9	**NOSE BUTTON**	• Rotating stainless-steel hemisphere (.200" Dia) contacts object being pushed – also acts as a Reverse stop. Polished; hardened by heat-treatment.)
10	**NOSE BUTTON WASHER**	• Assures metal-to-metal contact between Nose Button and Driveshaft to insure Nose Button straightness and good dynamics.
11	**REVERSE STOP CUSHION**	• Teflon or rubber (depending on Actuator velocity) donut produces a soft stop.
12	**HOUSING**	• <1" O.D. black anodized body. Vacuum compatible housing is unanodized.
13	**CABLE**	• 1/8" O.D. cable-coil with 7 wires.
14	**ENDCAP**	• Closes-up the actuator and provides strain-relief for the cable going to the servo.
15	**MOUNTING NUT**	• Nut with 0.55"O.D. secures the actuator onto its mounting surface. I.D. has ⅜-40" UNC threads.



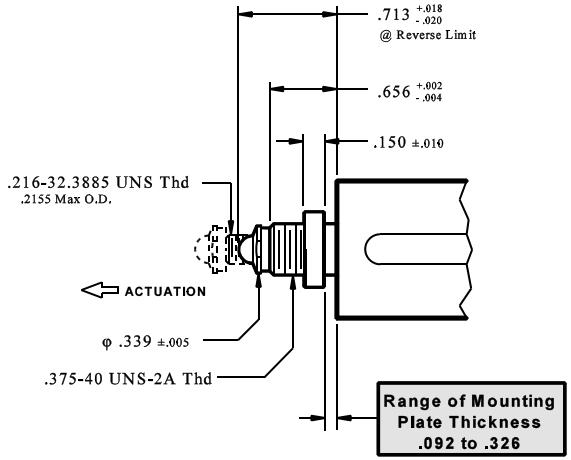
AVERAGE WEIGHT									
TRAVEL	0.25"	0.5	1"	2"	4"	6"	8"	10"	12"
oz.	4.3	4.6	4.8	7.9	11.2	13.3	16.4	19.5	22.6

16/5 SERIES (Standard) AVAILABLE GEAR RATIOS	
6.3:1	1670:1
11.8:1	3101:1
22:1	5752:1
41:1	10683:1
76:1	19813:1
141:1	36796:1
262:1	68245:1
485:1	126741:1
900:1	235067:1

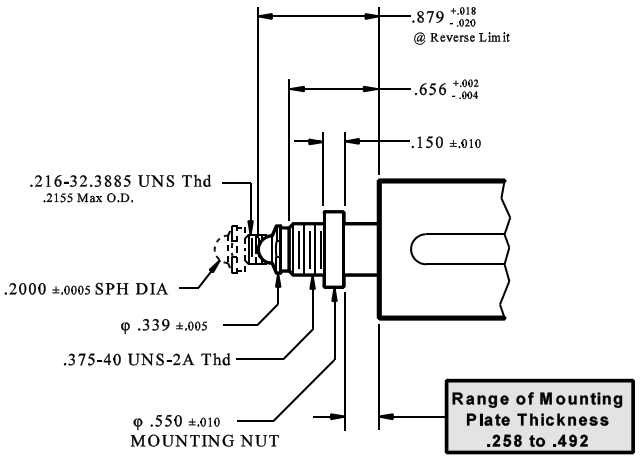
HIGHEST POSSIBLE GEARHEAD RATIO (16/5-series) PER MOTOR PER TRAVEL									
MOTOR	TRAVEL								
	0.25"	0.5"	1"	2"	4"	6"	8"	10"	12"
1616	1670	5752	5752	68245	235067	235067	235067	235067	235067
1624	41	41	41	485	68245	235067	235067	235067	235067
1717	Call Factory								
1724	Call Factory								



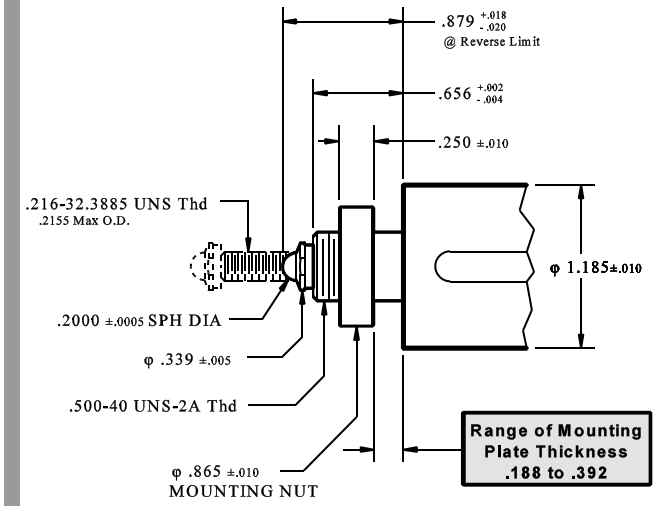
0.25" TRAVEL



0.5" TO 1" TRAVEL

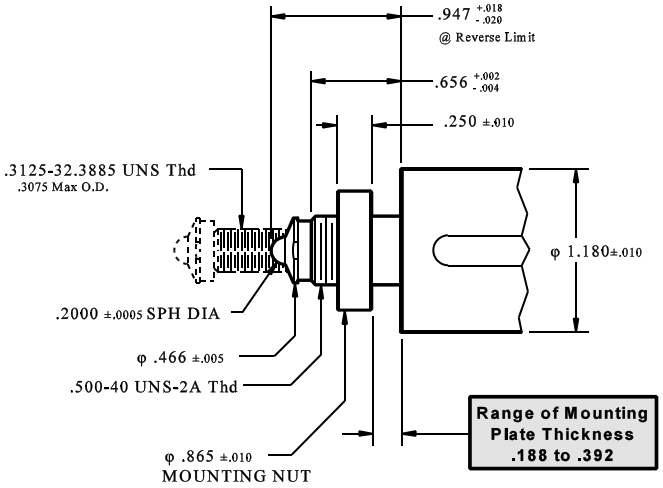


2" TO 4" TRAVEL



TRAVEL	
NOMINAL	ACTUAL +.047 -.027
0.25"	0.302
0.5"	0.530
1"	1.030
2"	2.030
4"	4.030
6"	6.030
8"	8.030
10"	10.030
12"	12.030

6" to 12" TRAVEL



1200-series Linear Actuators

Because these actuators do not have a built-in position encoder, they are shorter than the equivalent 1100-series. For example, the 0.5" travel is 0.8" shorter! Although 1200-series construction is similar to the 1100-series, the electrical connection is through an 18" two-conductor cable terminated in either a mono phone plug, MiniDIN8P connector, or stripped and tinned wires [-A option].

While the phone plug adapts to TS Product's line of controllers with built-in velocity servos, the MiniDIN8P interfaces to the SER3000-family of Analog Velocity Servos. Tinned leads are for connection to your controller/servo.

Unless you incorporate an external A-QUAD-B position encoding device, this actuator series is only for open-loop applications. We typically find these actuators in systems where an operator has visual feedback to move into final position with a joystick.

Two guiding slots on opposite sides of the housing prevent the motor from rotating as the leadscrew rotates. Marked keys in these slots also serve as a coarse indicator of position.

A shaped and polished Nose Button provides a precise contact point as well as a Reverse mechanical stop. The Forward mechanical stop is an elastomer cushion inside the housing connected directly to the leadscrew. The tabs in the guiding slots do not provide any ends-of-travel. In this way, the gearhead and motor are protected from the severe mechanical forces created by running into the ends-of-travel.

For pulling applications, a [-PPA] Push/Pull Adaptor option replaces the Nose Button.

For vacuum environment, all lubricants are space-qualified.

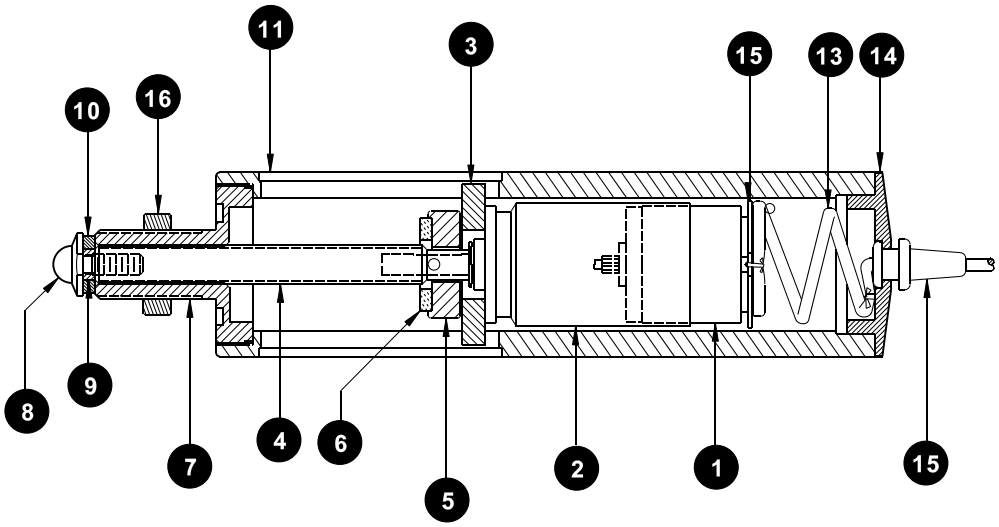
When controlling the 1200-series through either the 1200SC Speed Controller or 1200J Joystick Controller, you have full velocity and direction control with limit-of-travel sensing and *backing-off* the limit.

Major Features

- Shortest housing length
- Travels of ¼", ½", 1", 2", 4", 6", 8", 10", 12" [Custom=14", 16", 18"]
- Thrusts up to 300 lbs.
- Maximum velocity up to 17 mm/sec
- Pseudo-resolutions down to 1.8 ηin (45 ρm)
- Internal limit-of-travel/torque sensing through optional SER3000 Analog Velocity Servo
- Vacuum-compatibility option
- Axial or side cable discharge

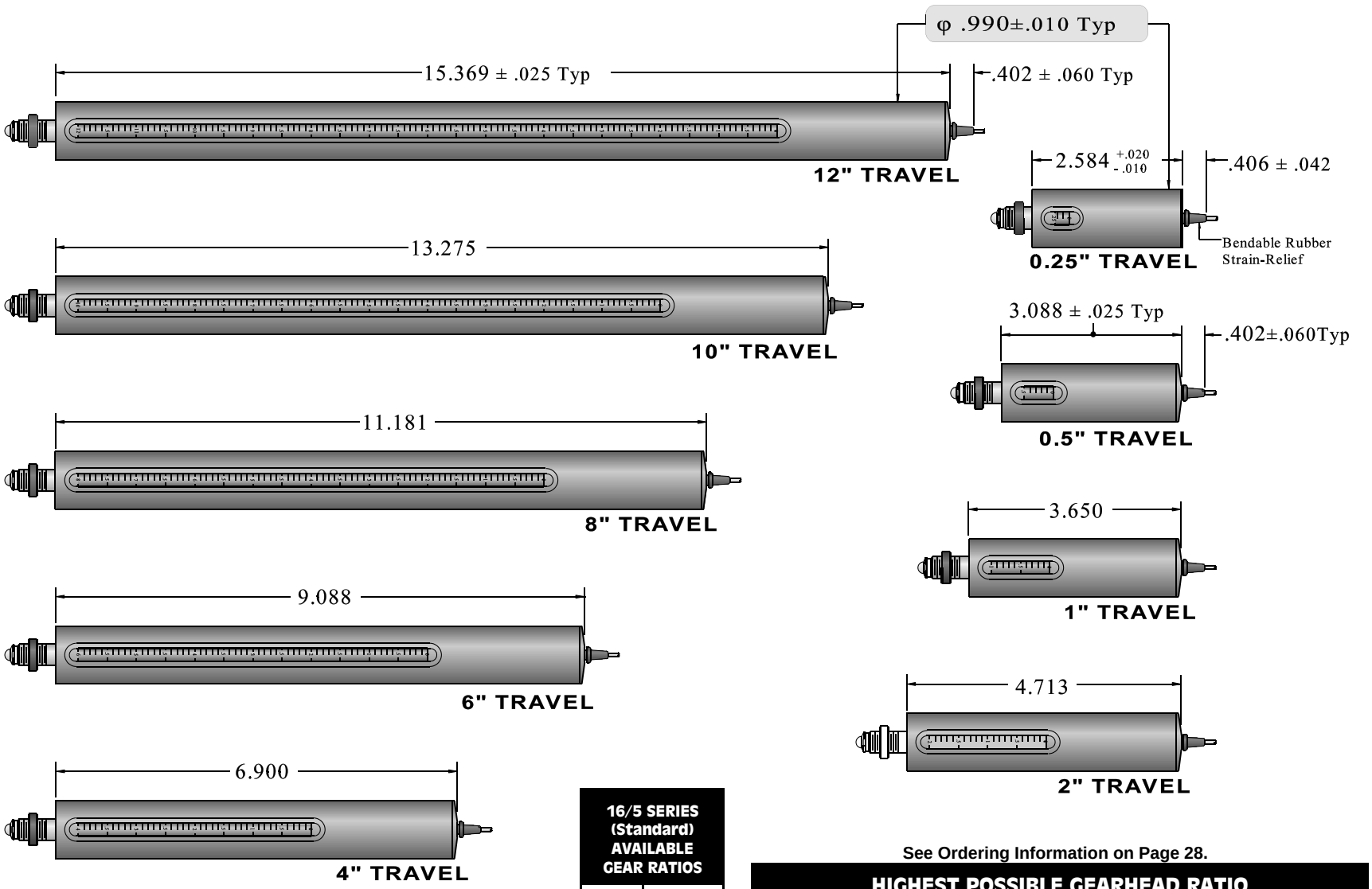
Typical Customizing

- Shorter housing
- Non-standard travels, such as 0.6"
- Thruster length variation
- Cable length variation
- Increased thrust capacity
- Adjustable thrust limit
- Custom Nose Button



MECHANICAL PARTS DESCRIPTION

1	**MOTOR**	• MicroMo 1616, 1624, 1717, or 1724 motor with armature voltage ranging from 3-24 volts (17,000 RPM maximum velocity).
2	**GEARHEAD**	• MicroMo 16/5 or 16/7 Gearhead with ratios from 3.71:1 to 235,067:1 depending on space available.
3	**KEY**	• Double-tabbed key holds the gearhead from rotating and prevents choking sideloads created by single-tabbed designs.
4	**DRIVESHAFT**	• Precision-ground stainless-steel with either 32.3885 TPI or 40.0000 TPI pitch converts rotary motion into linear movement – bonded to gearhead output shaft with Loctite adhesive rated at -65°F to 300°F temperature range.
5	**FORWARD STOP** [Stop Shaft Extension]	• Rigidly fixed on the Driveshaft, this rotating piece stops forward motion when it runs into the Nose Mounting.
6	**FORWARD STOP CUSHION**	• Teflon or rubber donut produces smooth, soft stops.
7	**NOSE MOUNTING**	• Stationary phosphor-bronze nut for Driveshaft. Outer mounting threads are ⅜-40 UNC.
8	**NOSE BUTTON**	• Rotating stainless-steel hemisphere (.200" Dia) contacts object being pushed – also acts as a Reverse stop. Polished; hardened by heat-treatment.
9	**NOSE BUTTON WASHER**	• Provides metal-to-metal contact between Nose Button and Driveshaft to insure Nose Button straightness and good dynamics.
10	**REVERSE STOP CUSHION**	• Teflon or rubber donut (depending on Actuator velocity) produces a soft stop.
11	**HOUSING**	• <1" O.D. black anodized body – unanodized for vacuum compatibility.
12	**CABLE SCRAPER**	• Thin disk keeps motor cable from getting stuck.
13	**CABLE**	• 1/8" O.D. cable-coil with 2 conds.
14	**ENDCAP**	• Closes-up the actuator and provides strain-relief for the cable going to the servo.
15	**CABLE STRAIN RELIEF**	• Rubber sheath decreases the possibility of damaging the Cable by bending.
16	**MOUNTING NUT**	• Nut with 0.55"O.D. secures the actuator onto its mounting surface. I.D. has ⅜-40" UNC threads.



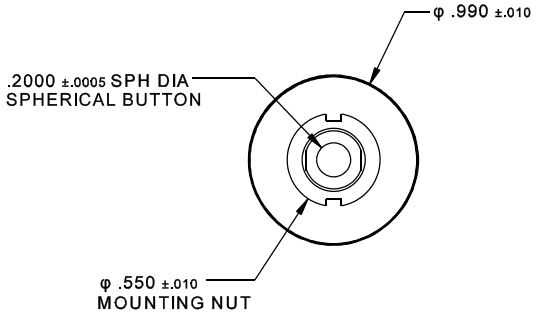
See Ordering Information on Page 28.

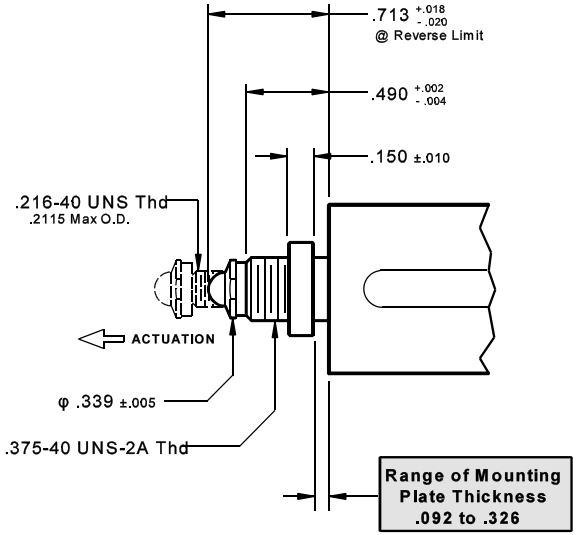
AVERAGE WEIGHT									
TRAVEL	0.25"	0.5	1"	2"	4"	6"	8"	10"	12"
oz.	3.6	3.8	4.2	4.9	6.1	7.4	8.5	9.7	10.9

16/5 SERIES (Standard) AVAILABLE GEAR RATIOS	
6.3:1	1670:1
11.8:1	3101:1
22:1	5752:1
41:1	10683:1
76:1	19813:1
141:1	36796:1
262:1	68245:1
485:1	126741:1
900:1	235067:1

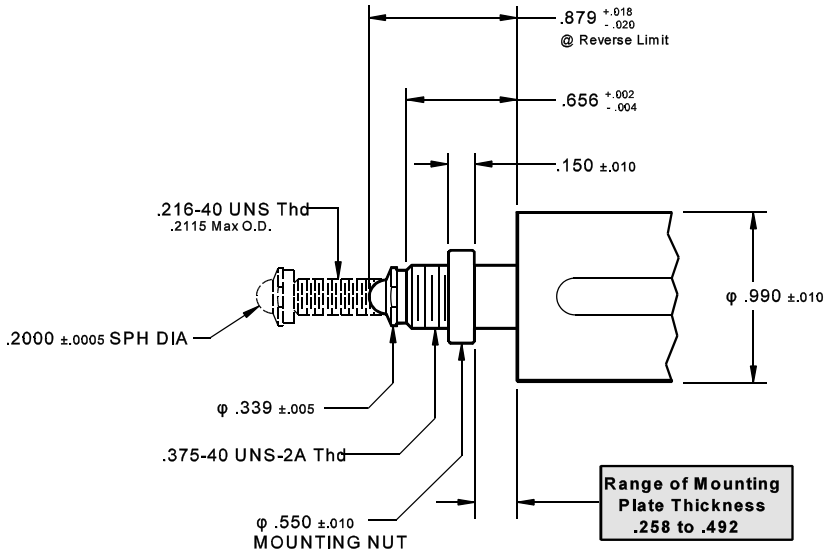
HIGHEST POSSIBLE GEARHEAD RATIO (16/5-series) PER MOTOR PER TRAVEL									
MOTOR	TRAVEL								
	0.25"	0.5"	1"	2"	4"	6"	8"	10"	12"
1616	485	19813	68245	68245	235067	235067	235067	235067	235067
1624	11.8	141	485	485	1670	5752	5752	5752	1670
1717	Call Factory								
1724	Call Factory								

0.25" TRAVEL





0.5" TO 12" TRAVEL



TRAVEL	
NOMINAL	ACTUAL +.047 -.027
0.25"	0.302
0.5"	0.530
1"	1.030
2"	2.030
4"	4.030
6"	6.030
8"	8.030
10"	10.030
12"	12.030

MOTOR/GEARHEAD SELECTION TABLE

1616 or 1624 Motors & 16/5 Gearheads

1200-Series Linear Actuator

Leadscrew = 40.00000 TPI

GEARHEAD RATIO	RESOLUTION[1]	VELOCITY[2] units/sec		MAXIMUM LOAD[3] (lbs)			
		1616 Motor	1624 Motor	1616 Motor		1624 Motor	
				Servo[4]	Stall[5]	Servo[4]	Stall[5]
6.3 [6.39683]	1.65 µm *65.1* µin	.65-13 mm *26-510* mils	.50-10 mm *20-390* mils	.7 .32kgm	1.2 .54kgm	2.8 1.3kgm	4.9 2.2kgm
11.8 [11.86420]	892 ηm *35.1* µin	.35-7.1 *14-280*	.27-5.4 *11-210*	1.3 .59kgm	2.3 .91kgm	5.2 2.4kgm	9.1 4.1kgm
22 [22.03351]	480 *18.6*	.19-3.8 *7.5-150*	.14-2.9 *5.7-110*	2.2 1.0kgm	3.8 1.7kgm	8.7 4.0kgm	15 6.9kgm
41 [40.86557]	256 *10.2*	.10-2.1 *4.0-81*	.078-1.6 *3.1-61*	4.0 1.8kgm	7.0 3.2kgm	16 7.4kgm	28 13kgm
76 [75.89319]	140 *5.49*	.055-1.1 *2.2-43*	42-840 µm *1.7-30* mils	6.8 3.1kgm	12 5.4kgm	27 12kgm	47 21kgm
141 [140.75917]	75.2 *2.96*	30-590 µm *1.2-23* mils	23-450 *.90-18*	13 5.7kgm	22 10.kgm	50 23kgm	87 40kgm
262 [261.40989]	40.5 *1.59*	16-320 *.63-13*	12-240 *.48-9.6*	21 9.1kgm	36 17kgm	56[6] [84]	100[6] [150]
485 [484.83713]	21.8 ηm *859* ηin	8.6-170 *.34-6.8*	6.6-130 *.26-5.2*	39 18kgm	67 31kgm	56 26kgm	100 45kgm
900 [900.41181]	11.8 *463*	4.7-93 *.18-3.7*	3.6-71 *.14-2.8*	56[6] [65]	100[6] [110]	56	100
1670 [1669.99451]	6.34 *250*	2.5-50 *.10-2.0*	1.9-38 *.075-1.5*	56 26kgm	100 45kgm	56	100
3101 [3101.41837]	3.41 *134*	1.4-27 *.053-1.1*	1.0-21 µm *41-810* µin	56	100	56	100
5752 [5752.20313]	1.84 *72.4*	.73-15 µm *29-570* µin	.56-11 *22-440*	56	100	56	100
10683 [10682.66295]	991 ρm *39.0* ηin	.39-7.8 *15-310*	.30-6.0 *12-240*	56	100	56	100
19813 [19813.14453]	534 *21.0*	.21-4.2 *8.3-170*	.16-3.2 *6.4-130*	56	100	56	100
36796 [36795.83984]	288 *11.3*	.11-2.3 *4.5-90*	.089-1.7 *3.7-74*	56	100	56	100
68245 [68245.27344]	155 *6.11*	.061-1.2 *2.4-48*	47-940 ηm *1.9-37* µin	56	100	56	100
126741 [126741.22210]	83.5 *3.29*	33-660 ηm *1.3-26* µin	25-500 *1.0-20*	56	100	56	100
235067 [235067.04688]	45.0 *1.77*	18-360 *.70-14*	14-270 *.54-11*	56	100	56	100

1 Pseudo-resolution – compared to 1000/1100-series Linear Actuators with 60-count encoders.

2 Typical 20:1 velocity range for *continuous* motion.

3 @ max velocity (50% No-Load Velocity). Typical variation of maximum load is ±35%. Suggested minimum load is 7 lbs or 50% of maximum for optimal operation.

4 While still inside a typical velocity servo window.

5 @ velocity = 0 (STALL).

6 Maximum thrust at STALL limited to 100 lbs to protect gearhead from damage. Maximum thrust at maximum velocity still within Servo Window is 56% of STALL thrust. Limitation by motor current reduction.

MOTOR/GEARHEAD SELECTION TABLE

1717 or 1724 Motors & 16/7 Gearheads

NOTE Contact factory for limitations on particular combinations of motor, gearhead ratio, and travel.

1200-Series Linear Actuator

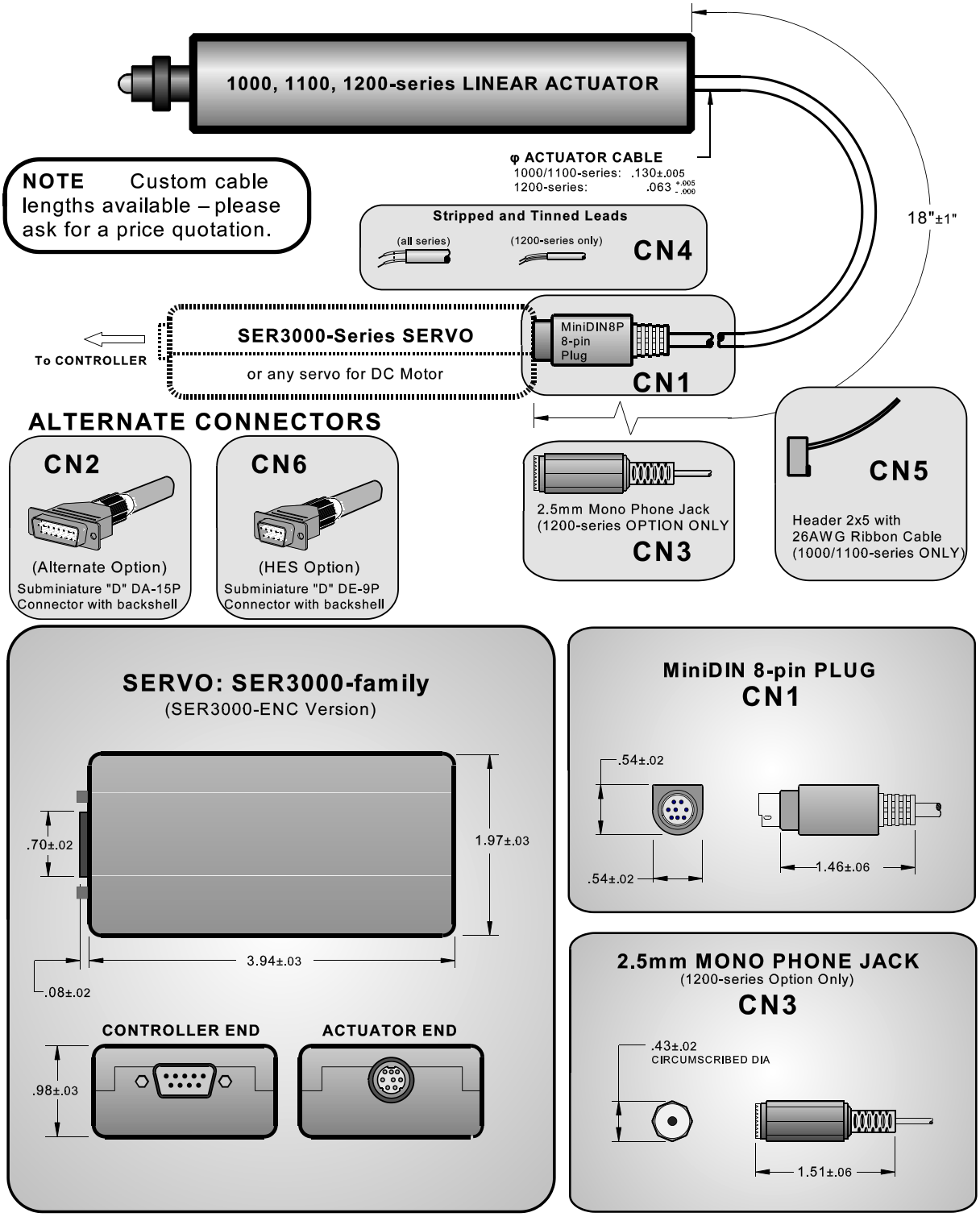
Leadscrew = 40.00000 TPI

GEARHEAD RATIO	RESOLUTION[1]	VELOCITY[2] units/sec		MAXIMUM LOAD[3] (lbs)			
				1716 Motor		1724 Motor	
		1717 Motor	1724 Motor	Servo[4]	Stall[5]	Servo[4]	Stall[5]
3.71 [ ]	2.85 µm *112* µin	.86-17 mm *34-680* mils	.53-11 mm *21-420* mils	2.1 .95kgm	3.7 1.7kgm	4.5 2.kgm	7.8 3.5kgm
14 [13.7959]	767 ηm *30.2* µin	.23-4.6 *9.1-180*	.14-2.9 *5.6-110*	7.0 3.2kgm	12 5.5kgm	15 6.8kgm	26 12kgm
43 [42.9206]	247 *9.71*	.075-1.5 *2.9-59*	46-920 µm *1.8-36* mils	19 8.6kgm	33 15kgm	40 18kgm	70 32kgm
66 [66.2204]	160 *6.29*	48-970 µm *1.9-38* mils	30-590 *1.2-23*	29 13kgm	51 23kgm	62 28kgm	108 49kgm
134 [133.5309]	79.3 *3.12*	24-480 *.94-19*	15-290 *.58-12*	51 23kgm	88 77kgm	108 49kgm	190 85kgm
159 [159.4195]	66.4 *2.61*	20-400 *.79-16*	12-250 *.49-9.7*	61 27kgm	100 48kgm	130 58kgm	220 100kgm
246 [245.9615]	43.0 *1.69*	13-260 *.51-10*	8.0-160 *.32-6.3*	93 42kgm	162 73kgm	165[6] [200]	300[6] [340]
415 [415.4294]	25.5 *1.00*	7.7-150 *.30-6.1*	4.7-95 *.19-3.7*	140 66kgm	250 110kgm	165 75kgm	300 140kgm
592 [592.1296]	17.9 ηm *704* ηin	5.4-110 *.21-4.3*	3.3-67 *.13-2.6*	165[6] [210]	300[6] [360]	165	300
989 [988.8914]	10.7 *421*	3.2-65 *.13-2.6*	2-40 *.078-1.6*	165 75kgm	300 140kgm	165	300
1526 [1525.7182]	6.94 *273*	2.1-42 *.083-1.7*	1.3-26 *.051-1.0*	165	300	165	300
2608 [ ]	4.06 *160*	1.2-25 µm *48-970* µin	.76-15 µm *30-590* µin	165	300	165	300
4365 [ ]	2.42 *95.5*	.73-15 *29-580*	.45-9.0 *18-360*	165	300	165	300
5647 [ ]	1.87 *73.8*	.57-11 *22-450*	.35-7.0 *14-270*	165	300	165	300

1 Pseudo-resolution due to No Encoder present.
2 Typical 20:1 velocity range for *continuous-style* motion.
3 @ max velocity (50% No-Load Velocity). Typical variation of maximum load for 1200-series is ±35%. Suggested minimum load is 7 lbs or 50% of maximum for optimal operation.
4 While still inside a typical velocity servo window.
5 @ velocity = 0 (STALL).
6 Maximum thrust limited to 300 lbs to protect gearhead teeth from damage. Maximum thrust at maximum velocity still within Servo Window is 56% of STALL thrust. Limitation by motor current reduction.

ENGINEERING NOTES

1000-family ELECTRICAL CONNECTION



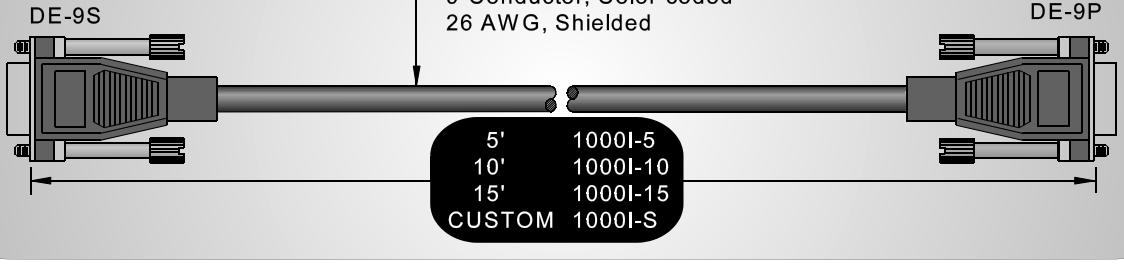
INTERCONNECT CABLES

"TO ACTUATOR OR SERVO" CONNECTOR

Use the Interconnect Cables to extend the short actuator cable to join the Servo or Controller. Also use them to connect SER3000-series Servos to Controllers. While some standard lengths are molded construction, the custom lengths are hand-fabricated.

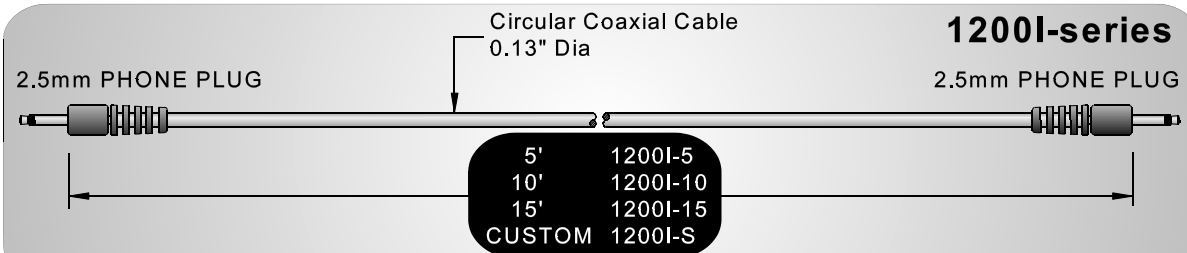
"TO CONTROLLER" CONNECTOR

1000I-series



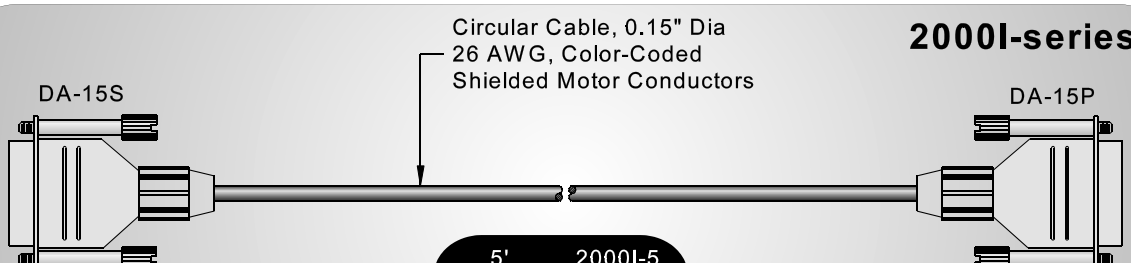
5'	1000I-5
10'	1000I-10
15'	1000I-15
CUSTOM	1000I-S

1200I-series



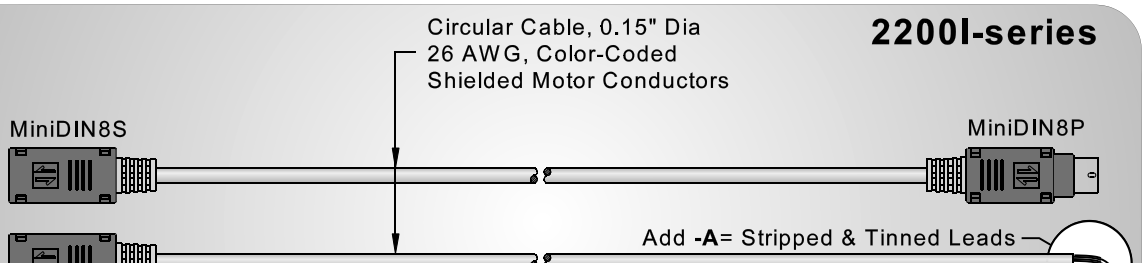
5'	1200I-5
10'	1200I-10
15'	1200I-15
CUSTOM	1200I-S

2000I-series



5'	2000I-5
10'	2000I-10
15'	2000I-15
CUSTOM	2000I-S

2200I-series



5'	2200I-5
10'	2200I-10
15'	2200I-15
CUSTOM	2200I-S

ORDERING GUIDE

All Linear Actuators can be ordered with this number sequence –

Series–Travel–Motor Size–Gearhead Ratio–Leadscrew Pitch–Options

Example 1000-05-1616-485-32-SD-V

ACTUATOR SERIES	TRAVEL[1] (inches)	MOTOR SIZE	GEARHEAD RATIO	LEADSCREW PITCH	OPTIONS
Brushed DC [Sensing Motor Conditions for Limit-of-Travel]	*1000*	*Brushed DC*	*16/5-series for brushed DC 1616 or 1624 motor*	**-32** 32.3885 TPI for actuators –	***No dash designator for OPTIONS indicates STANDARD CONFIGURATION with -NB1 Nose Button and axial discharge of control cable.***
1000 • Closed- loop • Non-rotating thruster • Robust, enclosed	**-05**	**-1616**	**-6.3** **-1670**	1000	**-B# Boot**
1100 • Closed-loop • Shorter housing • Rotating thruster	**-1**	**-1624**	**-11.8** **-3101**	1100	**-B05** ½" travel
1200 • Open-loop • Shortest housing • Rotating thruster	**-2**	**-1717**	**-22** **-5752**	2000	**-B1** 1" travel
Stepping [Integral Hall-effect Limit-of-Travel Sensors]	**-4**	**-1724**	**-41** **-10683**	2100	**-B2** 2" travel
2000 • Closed- loop • Non-rotating thruster • Robust, enclosed	**-6**[1]	*Brushless DC*	**-76** **-19813**	**-40** 40.0000 TPI for actuators –	**-NB# Nose Button**
2100 • Closed-loop • Shorter housing • Rotating thruster	*1100/1200*	**-3556**[1]	**-141** **-36796**	1100	**-NB1** Short radius [std]
2200 • Open-loop • Shortest housing • Rotating thruster	**-025**	*Stepping*	**-262** **-68245**	1200	**-NB2** Long radius
Brushless DC	**-05**	**-AM1524**	**-485** **-126741**	2100	**-NB3** Flat
3000[2] • Semi-custom	**-1**		**-900** **-235067**	2200	**-PPA** Push/Pull Adaptor
	-2		*15/5-series for AM1524 stepping motor*		**-PP# Push Pad**
	-4		**-6.3** **-1670**		**-PP1** Hemispherical, short-radius
	-6		**-11.8** **-3101**		**-PP2** Conical, short-radius
	-8		**-22** **-5752**		**-PP3** Hemispherical, long- radius
	-10		**-41** **-10683**		**-PP4** Conical, long-radius
	-12		**-76** **-19813**		**-PP5** Flat
	≥**-14**[2]		**-141** **-36796**		**-S**#a Custom modification designator
	2000		**-262** **-68245**		**-SD** Cable Side Discharge [Axial Discharge is std]
	-05		**-485** **-126741**		**-V** Vacuum Compatibility
	-1		**-900** **-235067**		**-ZB** Zero Backlash Gearhead
	-2		*16/7-series for brushed DC 1717 or 1724 motors*		**-CN# Connector**
	-4		**-3.71** **-415**		**-CN1** MiniDIN8P (1000, 1100, 1200, 2200)
	2100/2200		**-14** **-592**		**-CN2** DA-15P (2000, 2100)
	-025		**-43** **-989**		**-CN3** Mono 2.5mm Phone Plug (1200)
	-05		**-66** **-1526**		**-CN4** Tinned 18" Leads
	-1		**-134** **-2608**		**-CN5** Ribbon & Header (1000/1100)
	-2		**-159** **-4356**		
	-4		**-246** **-5647**		

[1] -05 represents 0.05" travel.
-1 represents 1.0" travel.

[2] Contact factory for additional information.

RESTRICTION for 1100/1200-series Linear Actuators
Choosing a MOTOR/GEARHEAD Combination for a certain TRAVEL

- The actuator's housing is a fixed length for a given travel – we often make custom modifications.
- Motors and gearheads vary in length – *more powerful* motors and *higher-ratio* gearheads have *longer length*.
- Space is required for internal cable's service-loop.

Therefore, each TRAVEL has a maximum gearhead ratio for a particular motor as shown on pages 12, 18, and 22. If you desire a combination beyond the limitation, you must use –

1. A smaller motor.
2. The next longer housing.
3. Cable *side discharge* (-SD) without internal cable's service-loop.

For example, **a 0.5" travel 1200-series with1624 motor and 900:1 gearhead will fit into a 1" housing.**

HIGHER GEARHEAD RATIOS

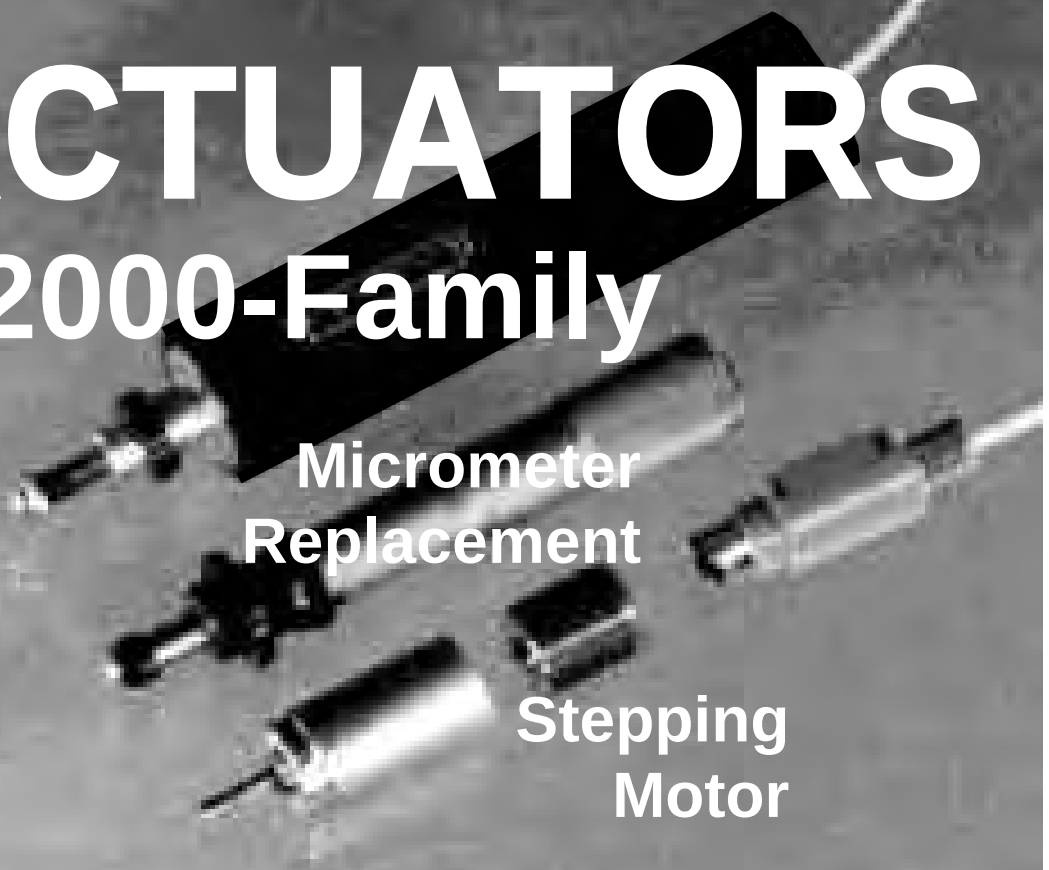
No matter what torque is available from the motor/gearhead combination, we limit the permissible maximum thrust to 100 lbs for the 16/5 gearhead. Higher thrust will either damage individual gear teeth, the spur gear support rods, or severely reduce component lifetime. Since *higher* gear ratios easily convert *small* motor torque into *high* thrust exceeding 100 lbs, there is no reason to use the more powerful but longer and slower 1624 motor since the 100 lb threshold has been already exceeded! (16/7 gearheads restricted to 300 lbs.)

PRECISION

MINIATURE

STEPPING-MOTOR LINEAR ACTUATORS

2000-Family



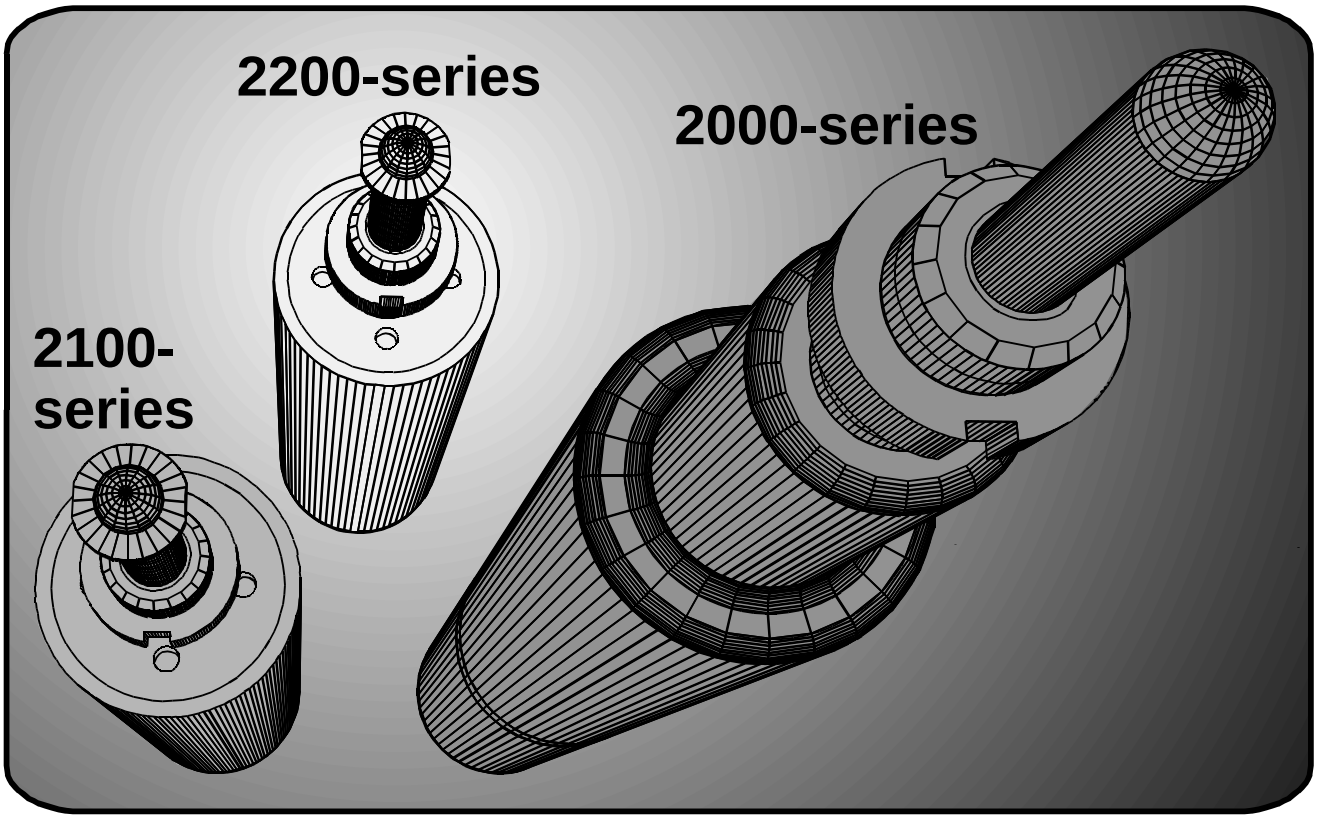
Micrometer Replacement

Stepping Motor

TS PRODUCTS, INC.
5550-2 North McGuire Road
Post Falls ID 83854-6506 USA
208-777-2771 FAX 208-777-9307

SECTION CONTENTS

	Stepping
Mechanical Specifications	
2000-series	32
2100-series	33
2200-series	34
Cabling	35
Ordering Information	36
Gearhead Selection Guide	37
Performance	38
Electrical Connection	39
Engineering Reference	40
HOME Sensing	40
Application Notes	42
Stepping Motor	42
Accuracy	42
Resolution	43
Motor Controllers	43
Drivers	44
Low Temperature	44
Vacuum Compatibility	44
Motor Comparison	45



WHAT IS A STEPPING MOTOR LINEAR ACTUATOR?

The 2000-family uses an Arsape Stepping Motor and leadscrew/nut to convert the motor's rotation into linear movement up to 4". *Stepping motors enable open-loop coordinate control without an encoder.* The 2000, 2100, and 2200 series produce a controlled thrusting movement by moving a plunger in and out of one end of a 1" OD cylinder. Eighteen different gearhead ratios provide a variety of thrusts, velocities, and resolutions.

In the 2000-series, a non-rotating nut moves along the screw and pushes a non-rotating plunger. In the 2100/2200-series, the screw itself mates with a threaded Nosepiece and rotates as it protrudes from the cylinder.

- **!** Travels to 4"
- **!** Thrusts to 100 lbs.
- **!** Velocities from 22 µin/sec to 0.82"/sec
- **!** Resolutions from 2 nanoinches to 0.0002"
- **!** Internal HOME sensor accurate to 10 µin
- **!** End-of-Travel sensors with overtravel
- **!** Adjusting Micrometer Replacement

2000-Series
Closed-loop operation
Integral position encoder
Non-rotating plunger

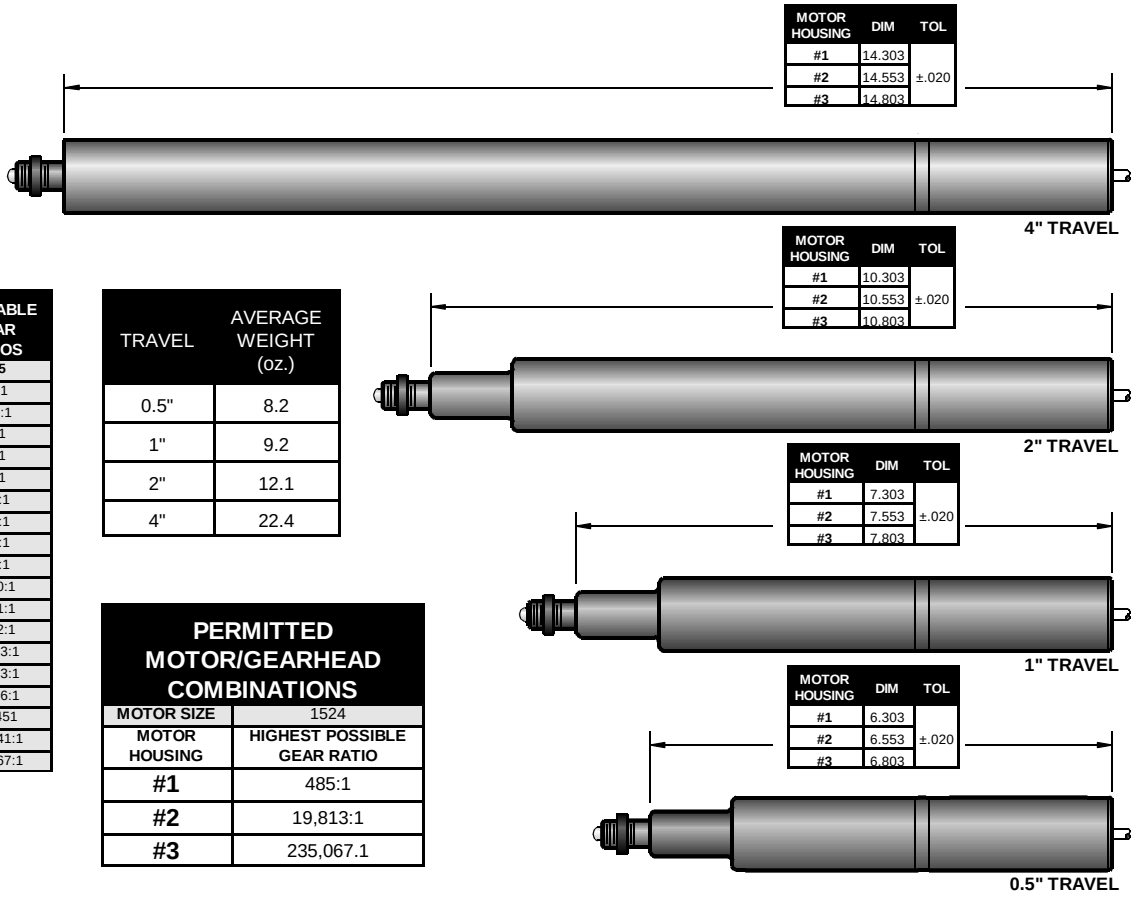
2100-Series
Closed-loop operation
Integral position encoder
Rotating plunger
Push/Pull capability
Short housing

2200-Series
Open-loop operation
Rotating plunger
Push/Pull capability
Shortest housing

2200-series
Coordinate control <u>without</u> built-in encoder!

ACTUATOR PHYSICAL PARAMETERS						
Travel		¼"	½"	1"	2"	4"
2000-SERIES [Closed-loop]						
Nominal Length[1]	Inches	NA	6.5	7.5	10.5	14.5
Nominal Weight[2]	Ounces	NA	8.2	9.2	12.1	22.4
2100-SERIES [Closed-loop]						
Nominal Length[1]	Inches	4	4.5	5.2	6.2	8.2
Nominal Weight[2]	Ounces	4.6	4.8	5.3	6.3	8.3
2200-SERIES [Open-loop]						
Nominal Length[1]	Inches	3.8	4	4.5	5.5	7.5
Nominal Weight[2]	Ounces	4.5	4.7	5.2	6.2	8.2
Operating Temperature	°F	-4 to +113				
Operating Air Pressure		10^{-9} Torr[3] to 3 Atmospheres				
Operating Relative Humidity	%	0 to 95				

[1]Approximate to mounting surface [2] Approximate [3] Order-**V** Option

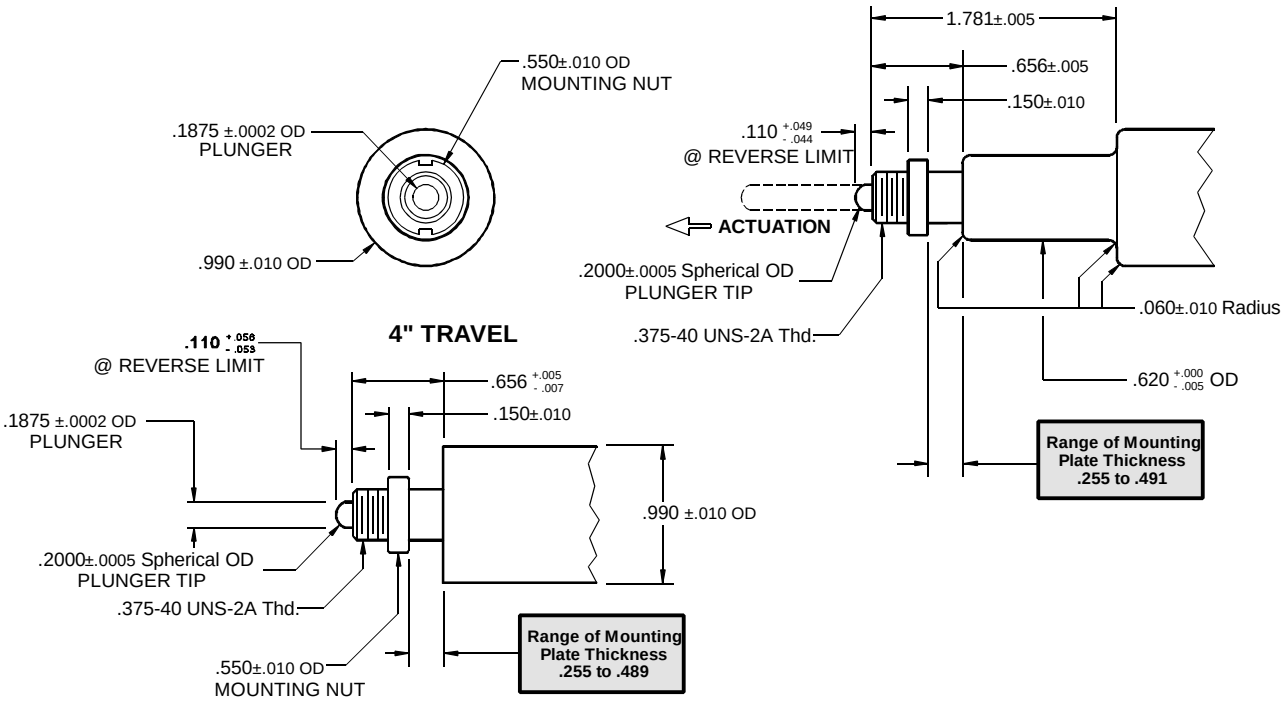


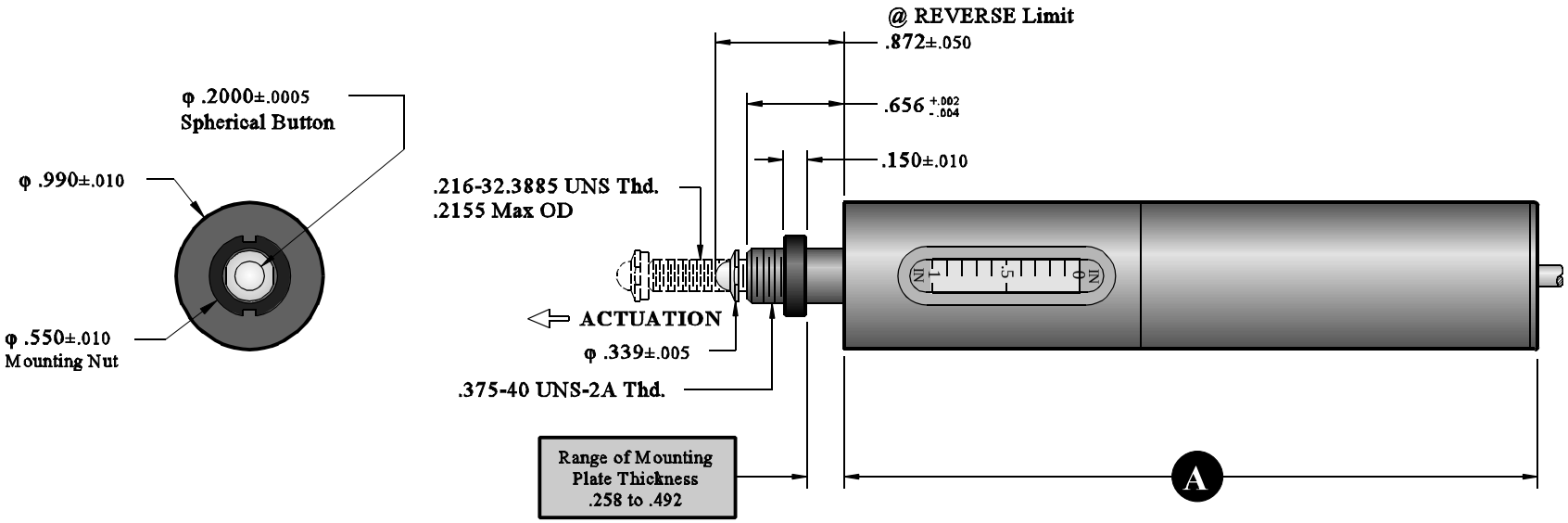
AVAILABLE GEAR RATIOS
15/5
6.3:1
11.8:1
22:1
41:1
76:1
141:1
262:1
485:1
900:1
1,670:1
3,101:1
5,752:1
10,683:1
19,813:1
36,796:1
68,2451
126,741:1
235,067:1

TRAVEL	AVERAGE WEIGHT (oz.)
0.5"	8.2
1"	9.2
2"	12.1
4"	22.4

PERMITTED MOTOR/GEARHEAD COMBINATIONS	
MOTOR SIZE	1524
MOTOR HOUSING	HIGHEST POSSIBLE GEAR RATIO
#1	485:1
#2	19,813:1
#3	235,067.1

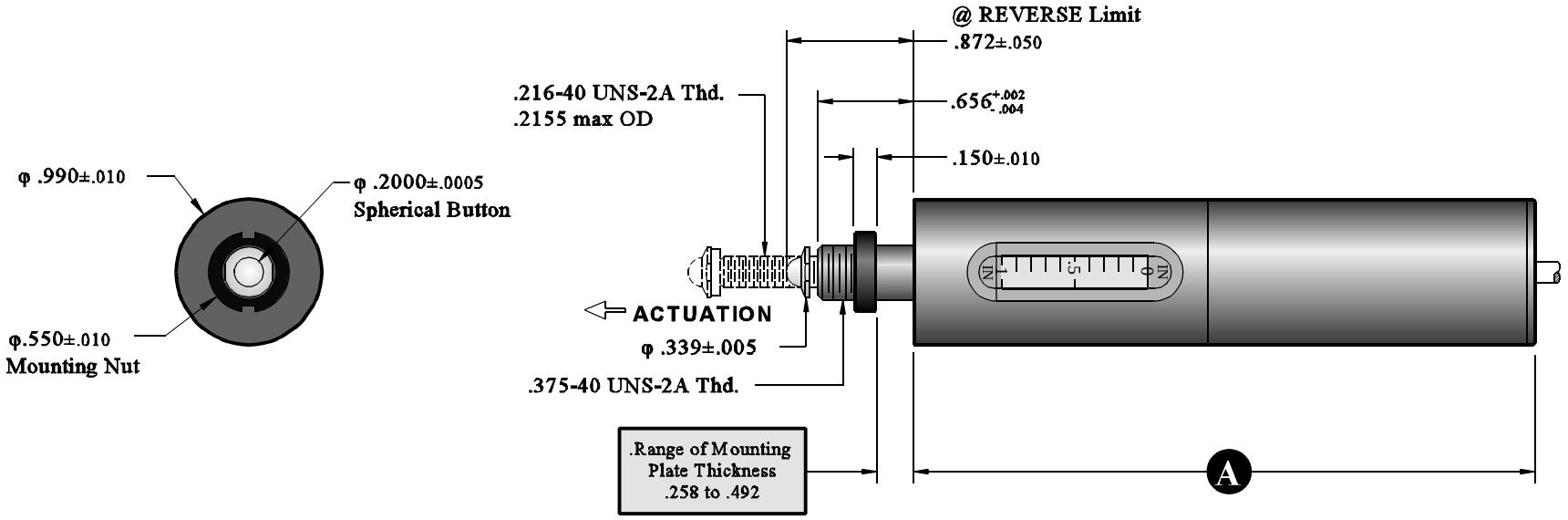
0.5" TO 2" TRAVEL





AVAILABLE GEAR RATIOS	
6.3:1	1670:1
11.8:1	3101:1
22:1	5752:1
41:1	10683:1
76:1	19813:1
141:1	36796:1
262:1	68245:1
485:1	126741:1
900:1	235067:1

TRAVEL	"X" (Critical Gear Ratio)	"A"±.020		AVERAGE WEIGHT (oz.)
		GEAR RATIO ~ X	GEAR RATIO š X	
0.25"	1670:1	3.951	4.692	4.6
0.5"	1670:1	4.201	4.942	4.8
1"	485:1	4.701	5.442	5.3
2"	41:1	5.701	6.442	6.3
4"	11.8:1	7.701	8.442	8.3

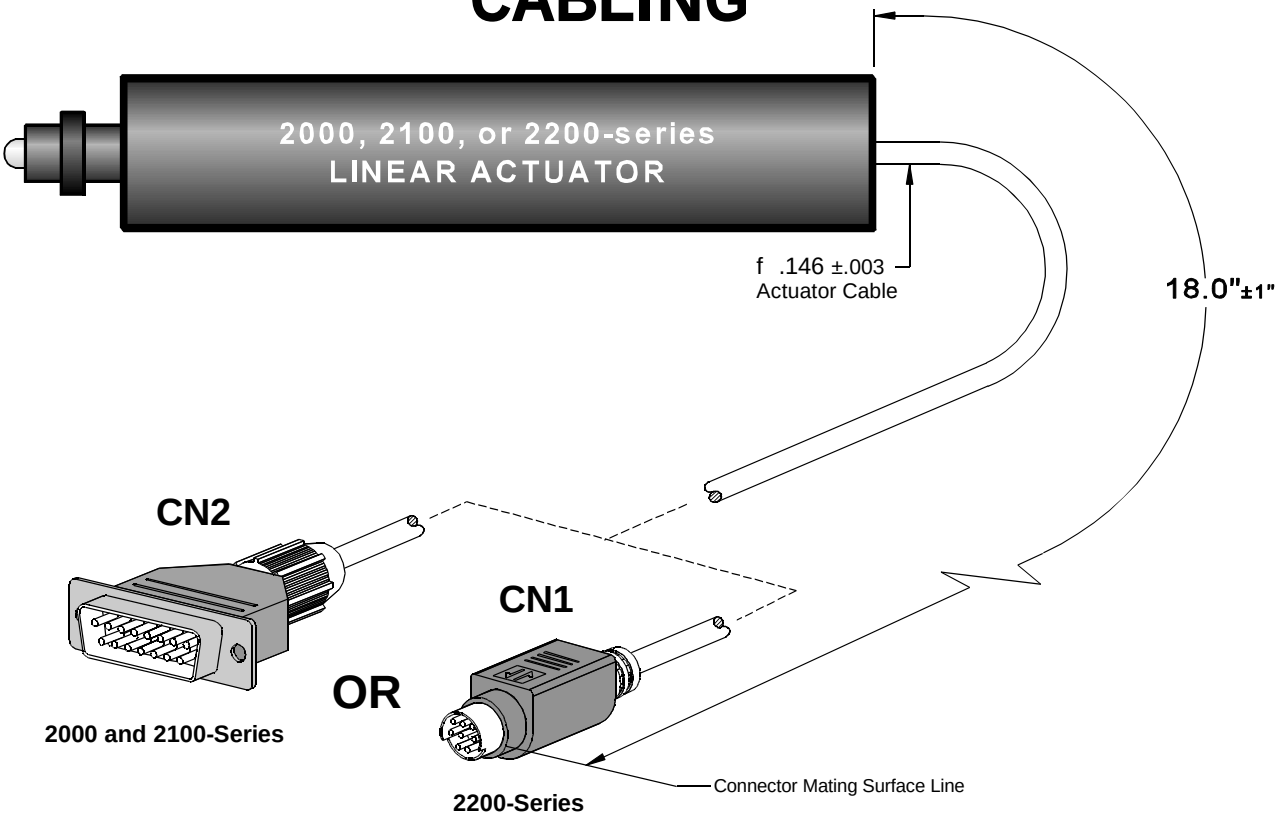


AVAILABLE GEAR RATIOS	
6.3:1	1670:1
11.8:1	3101:1
22:1	5752:1
41:1	10683:1
76:1	19813:1
141:1	36796:1
262:1	68245:1
485:1	126741:1
900:1	235067:1

TRAVEL	"X" (Critical Gear Ratio)	"A" ±.020		AVERAGE WEIGHT (oz.)
		GEAR RATIO ~ X	GEAR RATIO š X	
0.25"	19813:1	3.493	3.951	4.6
0.5"	1670:1	4.743	4.201	4.8
1"	485:1	4.243	4.701	5.3
2"	41:1	5.243	5.701	6.3
4"	11.8:1	7.243	7.701*	8.3

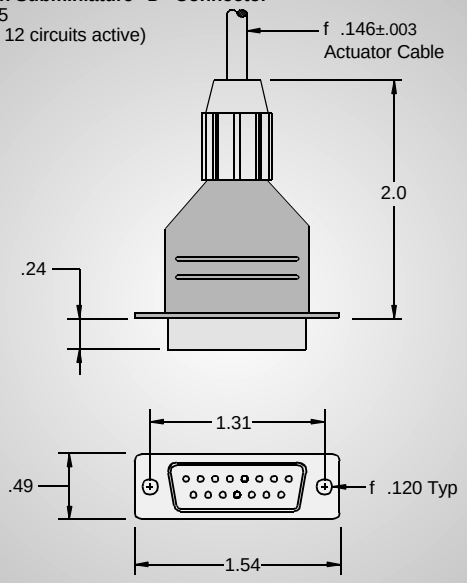
* This dimension is 8.442 with a 3101:1 or higher gear ratio.

CABLING



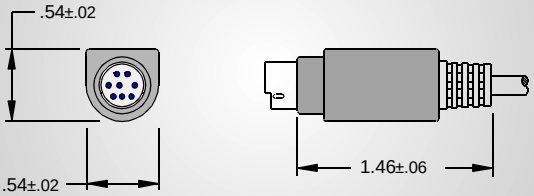
CN2

15-pin Subminiature "D" Connector
DA-15
(Only 12 circuits active)



CN1

8-pin MiniDIN Plug



TOLERANCE unless noted		
.X	.XX	.XXX
± .2	± .01	± .005

(All dimensions in inches)

ORDERING GUIDE

Order number example)

2100-1-AM1524-262-32-SD

ACTUATOR SERIES
2000 ! Closed-loop
! Non-rotating thruster
! Robust, enclosed
2100 ! Closed-loop
! Shorter housing
! Rotating thruster
2200 ! Open-loop
! Shortest housing
! Rotating thruster

TRAVEL Options

2000	Travel	2100/220	Travel
-05	½"	0	¼"
-1	1"	**-025**	½"
-2	2"	**-05**	1"
-4	4"	**-1**	2"
		-2	4"
		-4	

MOTOR STYLE
-AM1524 Arsape Stepping Motor
24 Full-steps/rev
Current mode (250mA max)

GEARHEAD RATIO 15/5 Options

-6.3	:1	**-262**	:1	**-10683**	:1
-11.8	:1	**-485**	:1	**-19813**	:1
-22	:1	**-900**	:1	**-36796**	:1
-41	:1	**-1670**	:1	**-68245**	:1
-76	:1	**-3101**	:1	**-126741**	:1
-141	:1	**-5752**	:1	**-235067**	:1

NOSE BUTTON Options
-NB1 Short Radius [Std.]
-NB2 Long Radius
-NB3 Flat
-PPA Push/Pull Adaptor

OPTIONS

		2000	2100	2200
-B	Boot	)	**T**	**T**
-NB#	Nose Button	)	**T**	**T**
-PP#	Push Pad	**T**	**T**	**T**
-SD	Side Discharge	**T**	**T**	**T**
-V	Vacuum Compatible	**T**	**T**	**T**
-ZB	Zero Backlash Gearhead	**T**	**T**	**T**

PUSH PAD Options
-PP1 Hemispherical, Short-Radius
-PP2 Hemispherical, Long-Radius
-PP3 Conical, Short-Radius
-PP4 Conical, Long-Radius
-PP5 Flat

LEADSCREW Options

	2000	2100	2200
-32 [32.3885 TPI]	**T**	**T**	)
-40 [40.0000 TPI]	)	**T**	**T**

IMPORTANT NOTICE

Not all combinations of motor, gearhead ratio, and travel are possible in the standard unmodified housing. Please see selection guidance charts on the pages of mechanical drawings.

GEARHEAD RATIO SELECTION TABLE

GEARHEAD RATIO 15/5 nominal (actual)	RESOLUTION				CURRENT mA	MAXIMUM LOAD @4000 fsps lbs		VELOCITY @250mA 4000 sps[1]	
	OPEN-LOOP 24 full steps/rev		CLOSED-LOOP 15-count encoder @ 4X						
	32.3885 TPI	40.0000 TPI	32.3885 TPI	40.0000 TPI					
	2000[2]/2100[3]	2100[3]/2200[4]	2000/2100	2100		2000/2100	2100/2200	2000/2100	2100/2200
6.3 (6.39683)	5.11 µm 201.1 µin	4.14 µm 162.8 µin	2.04 µm 80.4 µin	1.65 µm 65.1 µin	100 **250**[5] 500	1 **2** 4	1 **3** 6	20.8 mm/sec 820 mils/sec	16.9 mm/sec 664 mils/sec
11.8 (11.86420)	2.75 108.4	2.23 87.8	1.10 43.4	892 nm 35.1 µin	100 **250** 500	2 **4** 8	2 **5** 10	11.1 437	9.0 354
22. (22.03351)	1.48 58.4	1.20 47.3	593 nm 23.4 µin	480 18.6	100 **250** 500	3 **7** 14	3 **8** 16	6.0 235	4.8 190
41. (40.86557)	800 nm 31.5 µin	648 nm 25.5 µin	320 12.6	256 10.2	100 **250** 500	5 **13** 26	6 **15** 30	3.2 127	2.6 102
76. (75.89319)	430 16.9	348 13.7	172 6.78	140 5.49	100 **250** 500	9 **23** 46	10 **25** 50	1.7 68	1.4 55
141. (140.75917)	232 9.13	188 7.40	92.9 3.66	75.2 2.96	100 **250** 500	17 **43** 85	18 **46** 92	940 µm/sec 37 mils/sec	762 µm/sec 30 mils/sec
262. (261.40989)	125 4.92	101 3.98	50.0 1.97	40.5 1.59	100 **250** 500	30 **74** 100[6]	31 **77** 100[6]	508 20	406 16
485. (484.83713)	67.4 2.66	54.6 2.15	27.0 1.06	21.8 nm 859 nin	100 **250** 500	56 **100**[6] 100	57 **100**[6] 100	269 10.6	218 8.6
900. (900.41181)	36.4 1.43	29.5 1.16	14.5 nm 571 nin	11.8 463	100 **250** 500	100[6] **100** 100	100[6] **100** 100	145 5.7	117 4.6
1670. (1669.99451)	19.5 nm 771 nin	15.8 nm 624 nin	7.83 308	6.34 250	100 **250** 500	100 **100** 100	100 **100** 100	78.7 8.1	63.5 2.5
3101. (3101.41837)	10.53 415	8.53 336	4.21 166	3.41 134	100 **250** 500	100 **100** 100	100 **100** 100	40.6 1.6	33.0 1.3
5752. (5752.20313)	5.68 224	4.60 181	2.27 89.5	1.84 72.4	100 **250** 500	100 **100** 100	100 **100** 100	22.9 µm/sec 902 µin/sec	18.5 µm/sec 730 µin/sec
10683. (10682.66295)	3.06 120	2.48 97.5	1.22 48.2	991 pm 39.0 nin	100 **250** 500	100 **100** 100	100 **100** 100	12.2 482	9.9 390
19813. (19813.14453)	1.65 65.0	1.34 52.6	660 pm 26.0 nin	534 21.0	100 **250** 500	100 **100** 100	100 **100** 100	6.6 259	5.3 210
36796. (36795.83984)	888 pm 35.0 nin	719 pm 28.3 nin	355 14.0	288 11.3	100 **250** 500	100 **100** 100	100 **100** 100	3.5 136	2.8 110
68245. (68245.27344)	480 18.9	389 15.3	192 7.54	155 6.11	100 **250** 500	100 **100** 100	100 **100** 100	1.9 75	1.5 61
126741. (126741.22210)	258 10.15	209 8.22	103 4.06	83.5 3.29	100 **250** 500	100 **100** 100	100 **100** 100	1.0 41	838 nm/sec 33 µin/sec
235067. (235067.04688)	140 5.47	113 4.43	55.6 2.19	45.0 1.77	100 **250** 500	100 **100** 100	100 **100** 100	559 nm/sec 22 µin/sec	457 18

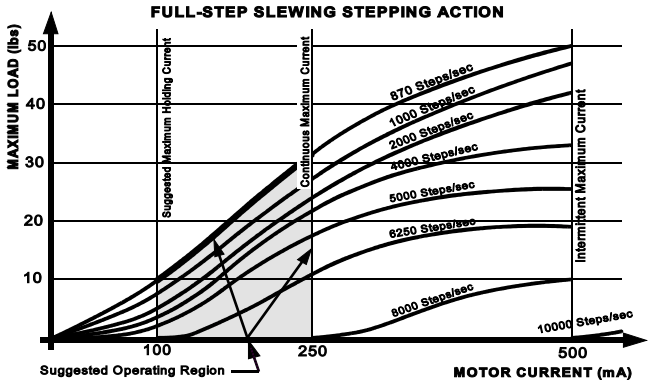
[1] Velocity for estimated Maximum Mechanical Power Point. You can run the motor faster but with less load capacity.
[2] All 2000-series have 32.38853 TPI leadscrew.
[3] 2100-series can have either 32.38853 or 40 TPI leadscrew.
[4] All 2200-series have 40.0000 TPI leadscrew.
[5] Factory-specified maximum continuous current in one winding only = 250 mA
[6] User must further limit the motor current to prevent exceeding 100 lbs of thrust.

PERFORMANCE of 2200-1-AM1524-41-40

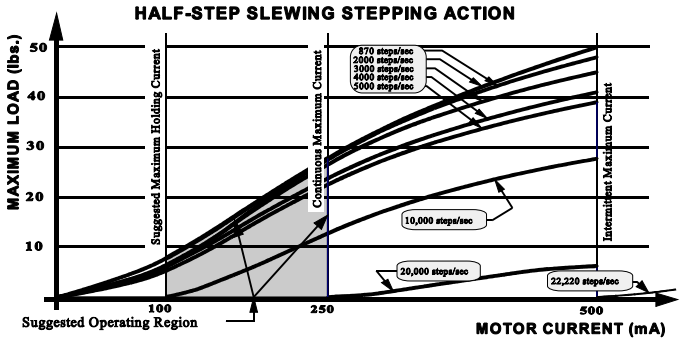
MAXIMUM LOAD for step synchronization as a function of motor winding current for various FULL-STEP velocities.

NOTES

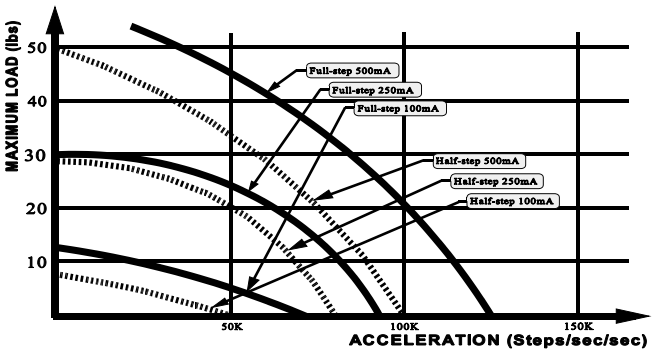
1. MAXIMUM LOAD = load causing step error.
2. INTERMITTENT MAXIMUM CURRENT– ON for less than 10 seconds with 10 seconds OFF minimum!
3. For 250 mA values, motor operated with 3.125 V_{dc} maximum voltage.



MAXIMUM LOAD to retain step synchronization as a function of motor winding current for various HALF-STEP velocities

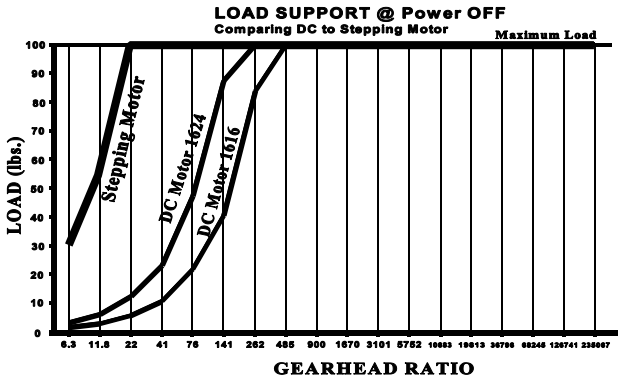


MAXIMUM LOAD to retain step synchronization as a function of Acceleration for various motor winding currents and step sizes



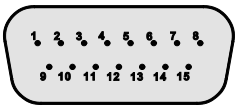
MAXIMUM LOAD Supported in Power OFF Condition comparing 2000-family with 1000-family Linear Actuators[1]

[1] Only applies during severe multi-G vibration. Under normal static conditions, **internal friction *always exceeds* external force thus preventing all spurious movement for both stepping and DC motors.**



NOTE – Proportionally scale performance data by gear ratio for other actuators.

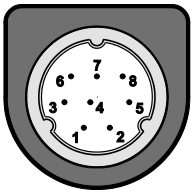
2000/2100-Series



Subminiature DA-15P

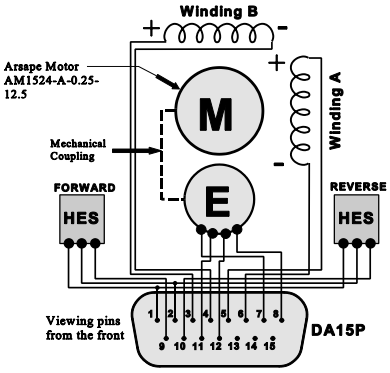
Circuit	Function
1	Sensor Supply
2	Sensor Return
3	Motor Phase A+
4	Motor Phase A-
5	Motor Phase B+
6	Motor Phase B-
7	Encoder Phase A
8	Encoder Phase B
9	Forward Limit Sensor
10	Reverse Limit Sensor
11	Encoder Return
12	Encoder Supply
13	NC
14	NC
15	NC

2200-Series



MiniDIN 8-pin

Circuit	Function
1	Motor Phase A+
2	Motor Phase A-
3	Motor Phase B+
4	Motor Phase B-
5	Sensor Supply
6	Sensor Return
7	Forward Limit Sensor
8	Reverse Limit Sensor

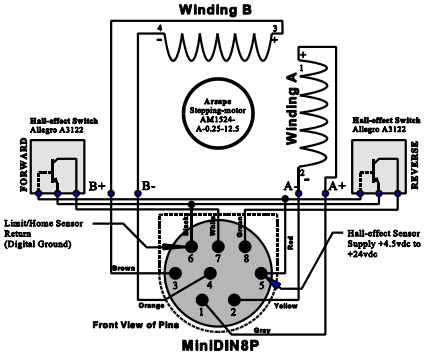


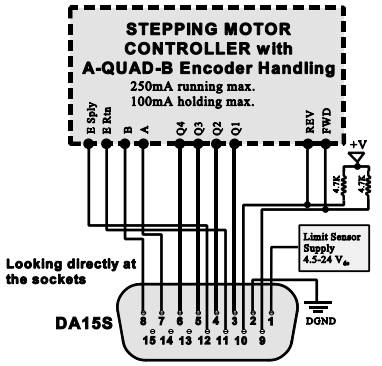
NOTE

The wiring schematics shown on this page represent –

- **2000-x-AM1524-76** and
- **2200-x-AM1524-262** only.

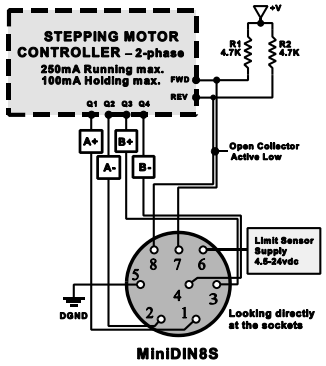
Other gearhead ratios and actuator styles have modified wiring to produce identical thruster movement for the same controller sequence.





HALL-EFFECT HOME/LIMIT SENSORS

- Open-collector
- Active low
- TTL/CMOS
- Hysteresis
- Overtravel



ELECTRICAL CONNECTIONS

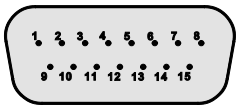
STEPPING-MOTOR PHYSICAL PARAMETERS					
ELECTRICAL PARAMETERS			**ANGULAR ACCURACY**		
Phase resistance	Ω	12.5	Absolute angular – 2 phases ON	% of Full Step	±3
Phase inductance @ 1Kz	mH	5.5	**MECHANICAL PARAMETERS**		
Nominal 2-phase current	A	0.25	Rotor inertia	$kgm^2 \cdot 10^{-9}$	45
Nominal single-phase current	A	0.35	Maximum radial load	lbs	.11
Back EMF amplitude	V/ksteps/second	3.5	Maximum axial load	lbs	.11
TORQUE PARAMETERS WITH BIPOLAR DRIVER			Maximum radial play – @ 2 Newtons	μin	.59
Nominal holding torque – 2 phases ON	oz-in	0.84	Maximum axial play – @ 2 Newtons	μin	5.9
Holding torque – 2x nominal current	oz-in	1.4	**OTHER PARAMETERS**		
Detent plus friction torque	oz-in	0.12	Dielectric Tests – for 1 minute	Vrms	500
THERMAL PARAMETERS			Resonance frequency	Hz	120
Thermal resistance coil-air	°C/W	55	Electrical time constant	μS	400
Maximum coil temperature	°F	266	Nominal acceleration	$krads/sec^2$	130
Ambient working temperature	°C	-20 to +45	Weight	oz	0.42
Thermal time constant	seconds	220	Step angle	degrees of arc	15

STEPPING-MOTOR TECHNICAL ASSISTANCE

Arsape Factory Representative /Distributor
Donovan Micro-Tek, Inc.
50 Vista Lago Drive
Simi Valley, CA 93065
Voice 805-522-4330
FAX 805-522-4464

Distributor
MicroMo Electronics, Inc.
642 Second Avenue S.
St. Petersburg, FL 33701
Voice 813-822-2529
FAX 813-821-6220

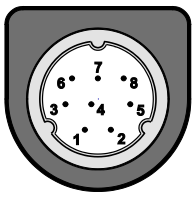
2000/2100-Series



Subminiature DA-15P

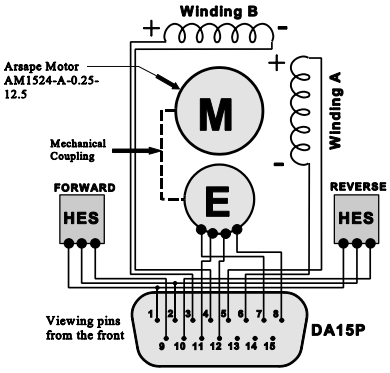
Circuit	Function
1	Sensor Supply
2	Sensor Return
3	Motor Phase A+
4	Motor Phase A-
5	Motor Phase B+
6	Motor Phase B-
7	Encoder Phase A
8	Encoder Phase B
9	Forward Limit Sensor
10	Reverse Limit Sensor
11	Encoder Return
12	Encoder Supply
13	NC
14	NC
15	NC

2200-Series



MiniDIN 8-pin

Circuit	Function
1	Motor Phase A+
2	Motor Phase A-
3	Motor Phase B+
4	Motor Phase B-
5	Sensor Supply
6	Sensor Return
7	Forward Limit Sensor
8	Reverse Limit Sensor

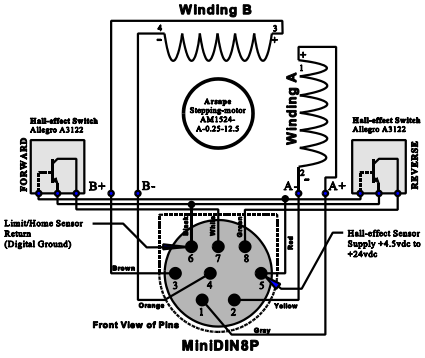


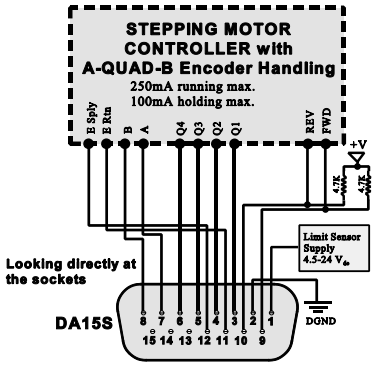
NOTE

The wiring schematics shown on this page represent –

- **2000-x-AM1524-76** and
- **2200-x-AM1524-262** only.

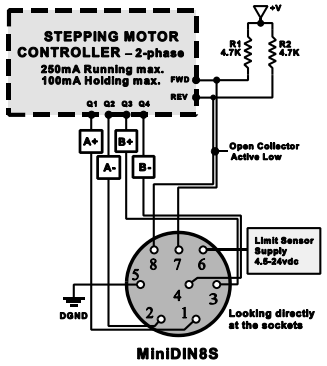
Other gearhead ratios and actuator styles have modified wiring to produce identical thruster movement for the same controller sequence.





HALL-EFFECT HOME/LIMIT SENSORS

- Open-collector
- Active low
- TTL/CMOS
- Hysteresis
- Overtravel



ELECTRICAL CONNECTIONS

STEPPING-MOTOR PHYSICAL PARAMETERS					
ELECTRICAL PARAMETERS			**ANGULAR ACCURACY**		
Phase resistance	Ω	12.5	Absolute angular – 2 phases ON	% of Full Step	±3
Phase inductance @ 1Kz	mH	5.5	**MECHANICAL PARAMETERS**		
Nominal 2-phase current	A	0.25	Rotor inertia	$kgm^2 \cdot 10^{-9}$	45
Nominal single-phase current	A	0.35	Maximum radial load	lbs	.11
Back EMF amplitude	V/ksteps/second	3.5	Maximum axial load	lbs	.11
TORQUE PARAMETERS WITH BIPOLAR DRIVER			Maximum radial play – @ 2 Newtons	μin	.59
Nominal holding torque – 2 phases ON	oz-in	0.84	Maximum axial play – @ 2 Newtons	μin	5.9
Holding torque – 2x nominal current	oz-in	1.4	**OTHER PARAMETERS**		
Detent plus friction torque	oz-in	0.12	Dielectric Tests – for 1 minute	Vrms	500
THERMAL PARAMETERS			Resonance frequency	Hz	120
Thermal resistance coil-air	°C/W	55	Electrical time constant	μS	400
Maximum coil temperature	°F	266	Nominal acceleration	$krads/sec^2$	130
Ambient working temperature	°C	-20 to +45	Weight	oz	0.42
Thermal time constant	seconds	220	Step angle	degrees of arc	15

STEPPING-MOTOR TECHNICAL ASSISTANCE

Arsape Factory Representative /Distributor
Donovan Micro-Tek, Inc.
50 Vista Lago Drive
Simi Valley, CA 93065
Voice 805-522-4330
FAX 805-522-4464

Distributor
MicroMo Electronics, Inc.
642 Second Avenue S.
St. Petersburg, FL 33701
Voice 813-822-2529
FAX 813-821-6220

ENGINEERING REFERENCE

Home Sensing Accuracy

Providing an accurate, repeatable HOME point is difficult. Although the Linear Actuators can provide an incremental resolution of a few nanoinches, traditional mechanical switches for limit-of-travel/home sensing are only accurate to a few mils at best. This means the HOME point could be in error by 500,000 resolution elements! However, the 2000-family uses Hall-effect switches for limit-of-travel and Home sensors. While the Hall-effect devices are much more accurate than mechanical switches, they still exhibit inaccuracies from the following sources:

- Differential thermal expansion in the actuator mechanical structure,
- Hall-effect switch temperature sensitivity,
- Losing step synchronism under an excessive load,
- Microstep uncertainty under load,
- Variable biasing from stray magnetic fields,
- Mechanical vibration and distortion,

1. Differential thermal expansion of dissimilar materials

In contrast to the stainless steel leadscrew, the actuator's housing is aluminum. The limit sensors are on the housing and the tripping magnets move with the leadscrew. Therefore, due to differential thermal expansion of these dissimilar metals, the position varies by temperature as a function of actuator travel.

In the 2000-series structure, the housing-to-leadscrew joint is *closest to the Reverse Limit sensor*. In contrast, in the 2100/2200-series structure, the housing-to-leadscrew joint is *far away from the Reverse Limit sensor*.

We calculated the following information from known coefficients of thermal expansion for the various materials used in the actuators. The error represents the apparent displacement of the thruster's Nose Button at both the FORWARD and REVERSE HOME sensor as the temperature changes.

THRUSTER POSITION ERROR in µin versus ºC CHANGE in TEMPERATURE					
TRAVEL	¼"	½"	1"	2"	4"
2000-series					
Reverse	na	-23	-31	-46	-77
Forward	na	-7	-4	3	17
2100/2200-series					
Reverse	+6	+3	-2	-13	-36
Forward	+16	+19	+24	+36	+58
+ Positive means that when you return to the Home switch, the Nose Button will be IN FRONT of where it was prior to the temperature change.					
- Negative means that the Nose Button will be BEHIND where it was prior to the temperature change.					

Internal housing temperature increase from running motor:

Since stepping motors continuously consume high current whether running fast or slow, they pump heat into the leadscrew and housing. Because it is a localized source of heat, the motor itself can produce distortions as the actuator temperature advances toward equilibrium.

For example, on a 2200-1 Linear Actuator –

- Simply holding an actuator in your hand can cause a 1-2 mil change in limit position. This can easily be 80 full-steps of the motor.
- Quick temperature changes can expand/-contract housing by 1-2 mils –
  1. Attaching to a cold plate,
  2. Holding in a warm hand,
  3. Contacting a work surface.

Typical Experimental Data

Initial Conditions

Temperature	70°F±10°F
	21°C±5°C
Actuator style	2200-01-AM1524-41
Microstepping	8x

Change 10°F room warm-up over 30 minutes

Result Moved REVERSE sensor's effective position by 700 µin (17.8 µm).

Change Holding in hand

Result FORWARD LIMIT = 200 µin.
REVERSE LIMIT = 1500 µin.

2. Hall-effect Switch Temperature Sensitivity

The 2000-family Linear Actuators use the Allegro Model 3122 Hall-Effect Switch. Its *operating point* can vary 5 µin/°C.

3. Losing Step Synchronism under Excessive Load

Typical of all stepping motors, if the external load exceeds the thrust capacity of the Linear Actuator, the motor will lose position by 4-step multiples. Under these conditions, HOME is not repeatable.

Operating Environment

To produce actuator resolution comparable with Hall-effect Switch accuracy, we make the following practical suggestions –

- Air temperature within ±½°F,
- Laminar air flow,
- Mount to heat conductor,
- Prohibit mechanical vibration,
- No touching of housing with hand.
- No variable pressure on housing.

4. Microstep Inaccuracy Under Load

Microstepping motor drivers vary the magnetic stator pole strengths to balance the rotor teeth somewhere between the *cardinal* steps. With many microstep subdivisions, the torque difference between adjacent microsteps may be smaller than system friction and load and the actuator will not move.

Without external torque, a stepping motor's rotor is in a stable resting position compared to the stator. To hold a stepping motor's rotor in place against an external torque, the magnets generate a larger opposing torque as the displacement between rotor and stator becomes larger. The greater the displacement – the greater the torque. If the external torque is higher than the motor's maximum torque, the rotor will slip to the next detent position.

Similarly, to move against an external torque, the motor must generate a larger torque. This torque is a function of both the offset between the rotor and its rest state as well as the relative current differences between the poles. When microstepping, maximum available torque for a fixed current occurs at the normal full-step detents. At the electronically-created microsteps between the full-steps, the number of steps correspondingly reduces the available torque.

If the external load is high enough, the motor may not even move. It may even rotate away from its expected position until the torque generated by the displacement exceeds the torque required.

5. Variable Biasing from Stray Magnetic Fields

Although the external magnetic fields may not be strong enough to trip the sensor, any field will move the trip point.

6. Mechanical Vibration and Distortion

Although the actuator housing is mechanically robust, you can easily experience HOME position errors while the housing flexes under an external driving mechanical vibration.

Switch Accuracy

With all factors being stable, the Hall-Effect Switch repeats within 10µin (0.4µm) – other error sources can often be an order of magnitude larger.

APPLICATION NOTES

STEPPING MOTOR

Theory of Operation

The AM1524-24-A-0.25-12.5 Stepping Motor has two phases and operates best from bipolar drivers. Its winding resistance is a low 12.5 ohms for continuous current operation not exceeding 0.25A for both phases ON simultaneously. During half-stepping, the single phase ON can be 0.35A without damage to the motor under normal conditions.

MicroStepping

In single-phase FULL STEP operation, an opposing pair of magnetic rotor teeth line up with the energized stator electro-magnets. To control a stepping motor in FULL STEP mode, the adjacent pair of electromagnets is energized to attract the rotor teeth to a new FULL STEP position. In dual-phase FULL STEP operation, all stator poles are active and of the correct magnetic polarity to cause rotation and maximum torque.

In HALF STEP operation, the phases alternate between both ON and only one ON. To provide constant torque with only one phase ON, motor drivers often raise the current by 50%.

In microstepping operation, the electromagnets are not fully-switched. Instead, the magnetic strength is less than full thus causing the rotor to balance somewhere between the stator poles. The accuracy of microstepping is a function of field strength repeatability as well as uniformity of the electro-magnets.

Dropping Steps

If the external load is too high for either starting velocity, acceleration rate, motor current, or running velocity, the motor can fail to take a step. After the step failure, its new position will be in error by multiple rotor teeth positions or 4 Full Steps for each tooth.

RECOMMENDATIONS

Arsape recommends no more than 4x micro-stepping. Because of the exact mechanical structure of the AM1524 motor, you cannot realize the assumed increased positioning accuracy. We have tested the motor at Full-Step, Half-Step, 2x, 4x, 8x, and 16x micro-stepping with satisfactory results –

POSITIONING ACCURACY

Ranked from Most Important

• **Leadscrew Pitch Irregularity**	±400µin max. (±5µm) The nominal lead-screw has a peak-to-peak wobble equivalent to 10µm of linear distance.
• **Thermal Expansion**	15µin/°C average
Thruster	25µin/°C per 1" of exposed leadscrew.
Reverse Limit	15µin/°C per 1" of travel.
Forward Limit	3µin/°C independent of travel
• **Mechanical Distortion**	External forces on the actuator housing cause deformations and metal compression – a function of force amplitude and direction.
• **Gear Eccentricity**	Unknown but finite eccentricity.

POSITIONING RESOLUTION

Resolution relates to the number of steps per linear distance. It represents the minimum controllable movement and is a function of leadscrew pitch, gearhead ratio, and the motor steps per revolution. It is not a measure of absolute accuracy.

In the best of conditions, the actuator is repeatable within the resolution. However, thermal drift, backlash, and load variations influence repeatability.

Setting Up the Motor Driving Parameters

Winding Current @25°C

Two phases ON simultaneously	0.25A
One phase ON	0.35A

The principal concern with excessive motor current is a temperature rise in the motor windings. High temperature will burn-off insulation causing winding shorts and distort the rotor bearings. In the Linear Actuator package, the heat conduction path is through the Gearhead Housing-to-Leadscrew-to-Nose Mounting/Housing-to- mounting plate. The heat also radiates from the motor-to-Housing-to-air. A second conduction path is Motor-to internal air-to Housing-to external air.

Minimum Velocity

There is no minimum velocity!

Maximum Velocity

The motor's electrical time constant limits maximum velocity and depends on the winding inductance. By attempting to move the rotor faster and faster, the available driving energy decreases less because of the dynamic resistance of the windings. While the Maximum Power Point is at 4000 steps per second (our recommended maximum velocity), the motor can operate at 10,000 steps per second with reduced maximum output torque.

Maximum Starting Velocity is a function of load. For a given load, this velocity will move the actuator without dropping rotor steps. Please see Performance Graph on Page Stepping 38. Use proportional scaling for other actuators.

Acceleration

See Performance Graph on Page Stepping 38. Use proportional scaling for other actuators.

Step Interval	
	Full
	Half
	Micro<8X

MOTOR CONTROLLERS

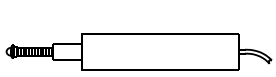
Controller

A typical Controller is a dedicated microprocessor-based computer with an accurate time base. Its low-level function is to prepare step and direction signals to start, accelerate, run, decelerate, and stop one or more stepping motors. Its high-level functions may include –

1. Synchronization of multiple motors.
2. Closed-loop encoder management.
3. Control or sensing of other machine events.
4. Operator's console.

Controllers are available in the following configurations –

1. Stand-alone or Computer-interface with RS-232 and/or IEEE-488 communications.
   Examples:
   1. Centent Company
   2. Compumotor
   3. Motion Science Inc.
2. Bus-based – IBM-PC, VME, STD.
   Examples:
   1. AMSI
   2. Motion Engineering, Inc.
   3. Motion Science Inc.
   4. ηDrive
   5. Precision MicroControl
3. PLC-based



Driver

Drivers deliver electrical power to motor in response to signals from the Controller. Typical signals are step pulses and direction level. It contains the logic to drive motors in full-step, half-step, or microsteps.

Bipolar Recirculating Chopper
(Power Dumping not necessary because the motor inductance is small.)
Examples:

1. AMSI
2. Compumotor
   For low current motors, controllers combine with drivers.

Desirable Features:

1. Step selection
   - Full
   - Half
   - Micro
2. Adjustable Microstep Current Profiles
   - Sinusoidal
   - Filled out
   - Trimmed
3. Automatic current reduction a certain time after last step pulse.
4. Pulse Width Modulated power delivery for more accurate microstepping.
5. Current modification for torque equalization for half-steps and microsteps.

VACUUM COMPATIBILITY

Laboratory testing demonstrates that the Arsape motor operates with expected torque at less than 10^{-5} Torr.

The 2000-family of Linear Actuators is specially-prepared to operate in a deep vacuum – order option **-V**. We use the following components –

- ■ Lubricant
  - Brayco Micronic 815Z
  - Perfluorinated polyether
  - Chemically inert
  - Compatible with rocket propellants and oxidizers
  - Intended for aerospace use
  - Vapor Pressure @ 38°C = $1x10^{-9}$ Torr

  OR

  - DuPont KRYTOX 143AB
  - Fluorinated oil (perfluoroalkylpolyether) specially formulated for aerospace, nuclear, and chemical process industries.
  - Vapor Pressure @ 38°C is $5x10^{-6}$ Torr.
- ■ Bonding
  - 3M Scotch-Weld 2216 Epoxy Adhesive.
- ■ Cable
  - Belden 9505 (Teflon) or equivalent.
- ■ Motor
  - Vented, cleaned, and relubed.
- ■ Gearhead
  - Vented, cleaned, and relubed.

LOW TEMPERATURE COMPATIBILITY

Test Temperature	Winding Resistance	Heat Dissipation
-196.2°C (78°K)	13% change	6.5 mW
-269.2°C (4°K)	1.9% change	1 mW

MOTOR COMPARISON: Stepping to Ironless-core DC

SPECIFICATIONS	Units	STEPPING	IRONLESS-CORE DC	
		AM1524-A	MM1624[3]	MM1724[3]
Lifetime	hours	>5000[1]	2000-5000[2]	2000-5000[2]
Acceleration	Krads/sec^2 (Maximum @ No Load)	130	71.6	105
No Load Velocity	RPM	14,000	13,000	8,000
Stall Torque	oz-in	0.53	0.6	1.49
Holding Torque	oz-in	0.6	0.6	
Detent + Friction	oz-in	0.12	0.013	0.016
Operating Temperature		266°F maximum -20°C to +45°C (-4°F to 113°F)	-30°C to 100°C (-22°F to 212°F)	
Rotor Inertia	$\cdot 10^{-3}$ oz-in-sec^2	6.4	0.85	1.44
Resonance	Hz	120	None	None
Mechanical Power	watts	1.55	1.5	2.2
Conceptual Position Control		Simple	Difficult	Difficult
Actual Position Control		Complex	Moderate	Moderate
Noise		Noticeable	Silent	Silent
Smoothness		Jerky[4]	Zero cogging	Zero cogging
Apparent Acceleration		Moderate	High	High
Loss of Position		Possible if open-loop	Never	Never
Package Size		15mm OD 24mm Length	16mm OD 24mm Length	17mm OD 24mm Length
Weight	oz	0.42	0.75	0.93
Magnetic Material		Samarium Cobalt	Alnico	Samarium Cobalt

[1] Limited by bearings
[2] Limited by brush life
[3] @ 12vdc
[4] Improved by half or microstepping

Comparative Comments

Smoothness Important for mechanical set-ups where external vibration will cause resonance and take time to dampen out. Laboratory technicians know that pumping mechanical energy adversely affects microscopes and other high magnification devices. In particular, RESONANCE would be a disaster if the motor remained at resonance.

Noise Obvious ramp-up and ramp-down audio characteristic of stepping motors. Ironless-core DC motors have almost no noise. The spur gearheads have some noise.

Detent Stepping motors by their design have detent but DC motors never have detent. Both have friction.

Inertia Because the stepping motor has moving magnets, it inherently has much higher inertia thus reducing its acceleration.

Temperature Because current always flows through the stepping motor windings, it easily gets hot. In DC motors, current is only consumed to move the motor. At rest, no current is used.

Drivers

At first, it seems more simple to drive stepping motors – give it a step and it moves one step. However, it's not really a STEP and the winding current must be switched in a complex and precise manner to cause movement. This switching substitutes for the DC motor's commutation. In principle, you can run a DC motor by direct connection to a battery.

Switching Accuracy

It's extremely important to NOT have clock jitter during switching times. Clock jitter will freeze-up the motor at higher velocities.

Phase Switching

The tables below show relationship between Thruster direction and motor phase switching sequence. Be sure to connect internal sensors in proper Forward/Reverse relationship.

STEPPING MOTOR DRIVING SEQUENCE

PHASE POLARITY		Thruster Direction[3]	Direction through Switching Sequence
A	B		
✚[1]	✚[2]	**FORWARD** (Protruding Thruster)	▼
▬	✚		
▬	▬	**REVERSE** (Retracting Thruster)	▲
✚	▬		

1 ✚ ➡ Conventional current flowing from Pin1 to Pin2 on MiniDIN8P (see page 39)
2 ✚ ➡ Conventional current flowing from Pin3 to Pin4 on MiniDIN8P (see page 39)
3 All actuators and gearhead ratios produce identical Thruster movement direction.

CURRENT LIMITED OPERATION

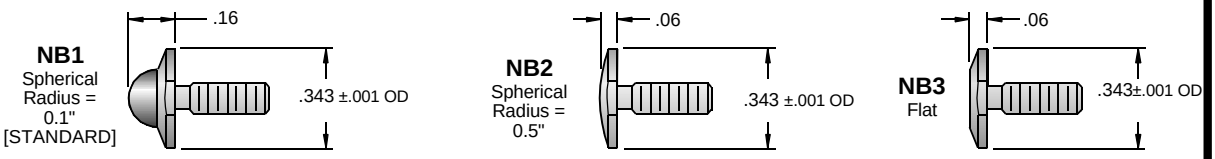
The Arsape motor is designed to operate in *CURRENT MODE* – torque is produced by supplying varying amounts of current at voltages less than 500 vdc. Since you control the amount of current to the motor and therefore its output torque, there is a danger of causing mechanical damage to gearheads with high ratios. We recommend limiting the current to produce no more than 100 lbs of thrust. In addition to a maximum current of 250 mA, the following table shows the recommended maximum current for each gearhead ratio:

15/5 GEARHEAD RATIO	MAX LOAD (lbs)	MAX CURRENT (mA)	15/5 GEARHEAD RATIO	MAX LOAD (lbs)	MAX CURRENT (mA)	15/5 GEARHEAD RATIO	MAX LOAD (lbs)	MAX CURRENT (mA)
6.3	4	250	262	100	169	10683	100	4.14
11.8	7	250	485	100	91.3	19813	100	2.23
22	13	250	900	100	49.2	36796	100	1.20
41	24	250	1670	100	26.5	68245	100	0.649
76	45	250	3101	100	14.3	126741	100	0.349
141	80	250	5752	100	7.70	235067	100	0.188

DC-MOTOR &
STEPPING MOTOR
LINEAR ACTUATOR

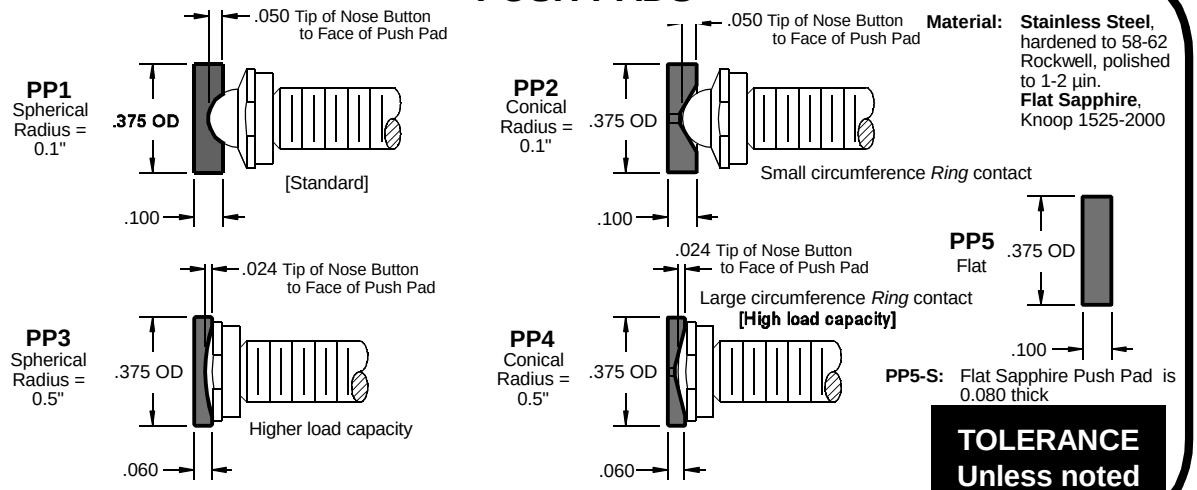
ACCESSORIES and PRICING

NOSE BUTTONS



Material: Stainless Steet, hardened to 58-62 Rockwell, polished to 1-2µin.

PUSH PADS

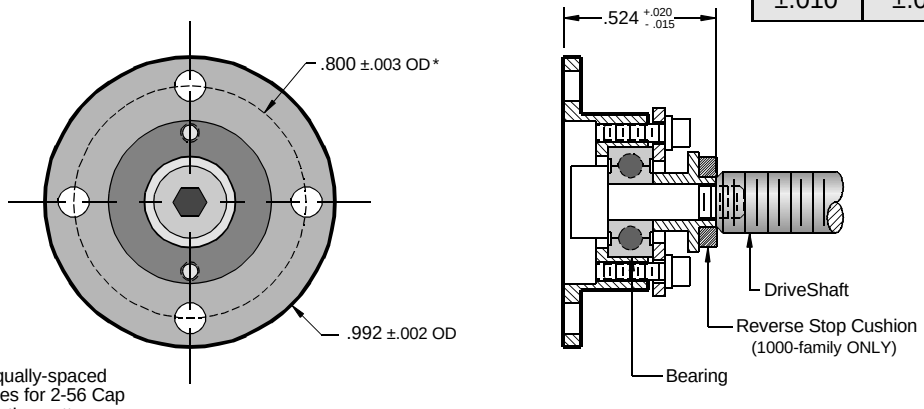


Material: **Stainless Steel**, hardened to 58-62 Rockwell, polished to 1-2 µin.
Flat Sapphire, Knoop 1525-2000

PP5-S: Flat Sapphire Push Pad is 0.080 thick

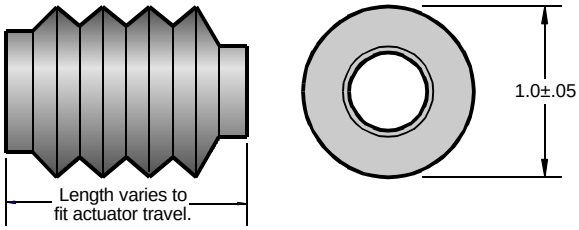
TOLERANCE Unless noted	
.XX	.XXX
±.010	±.005

PUSH/PULL ATTACHMENT

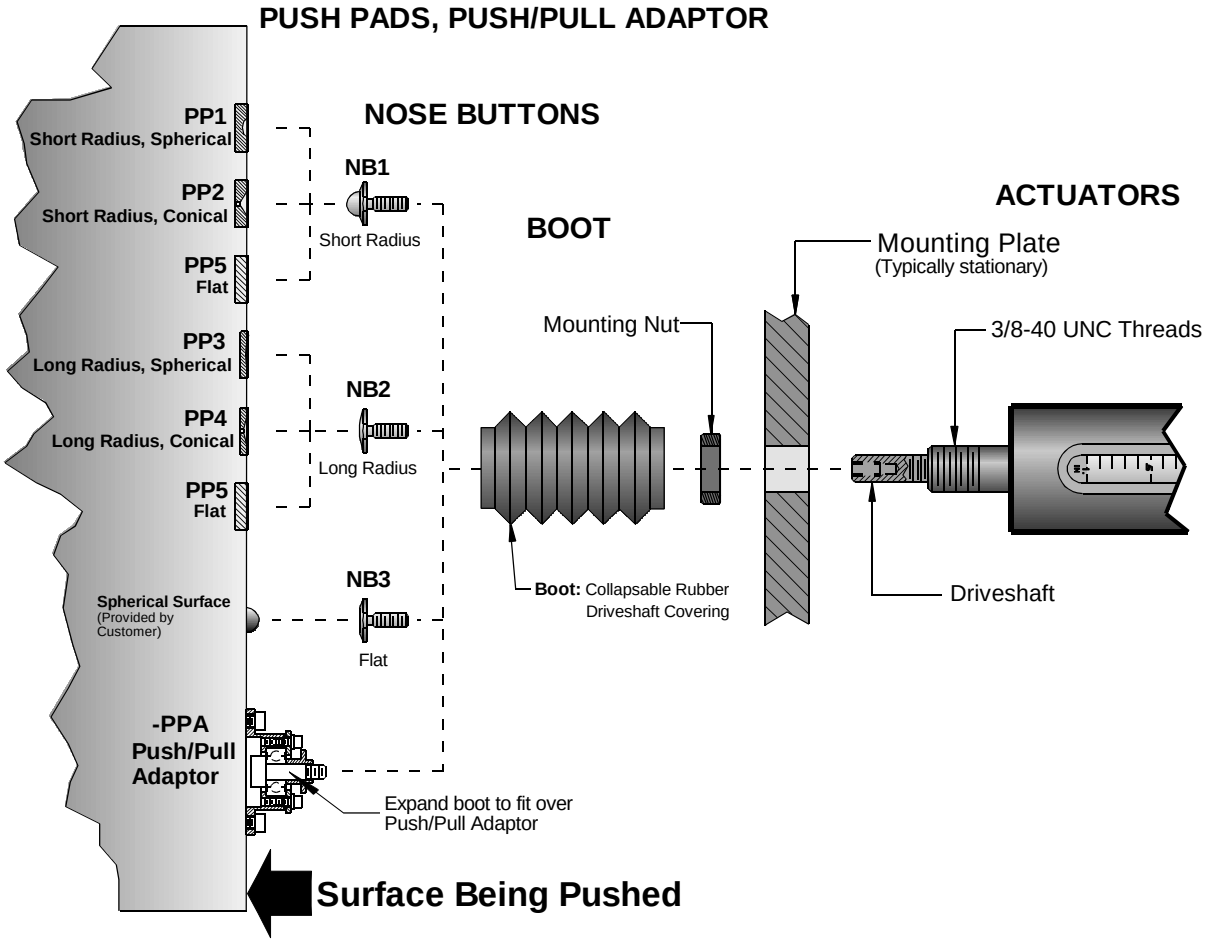


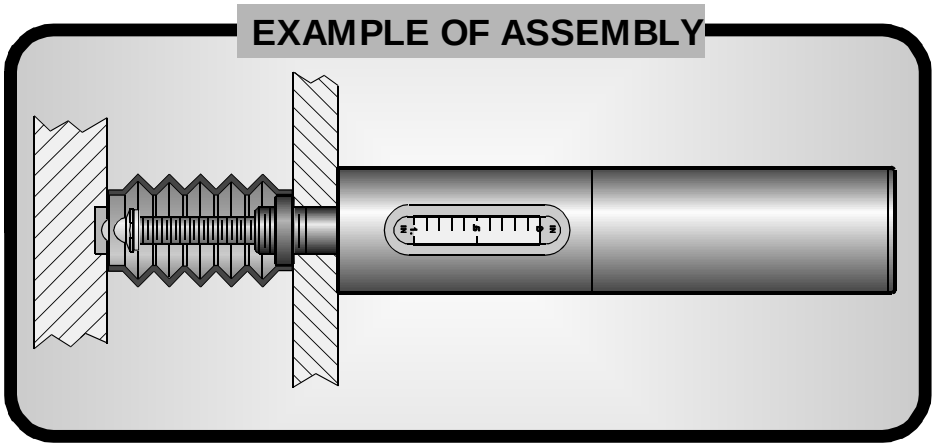
* NOTE: 4 equally-spaced mounting holes for 2-56 Cap screws. Mounting pattern on .800±.005 OD.

BOOT

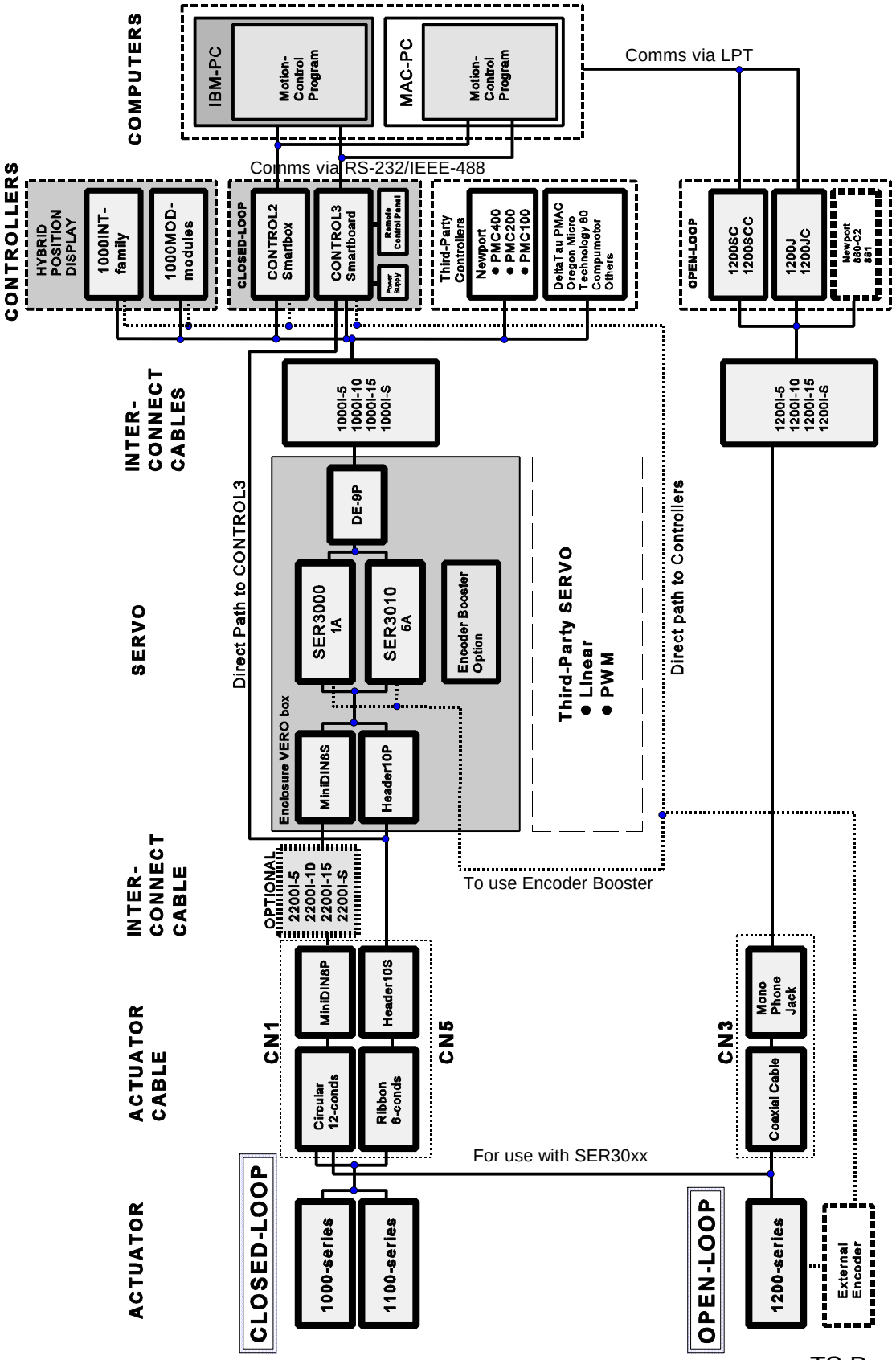


ACTUATOR MOUNTING

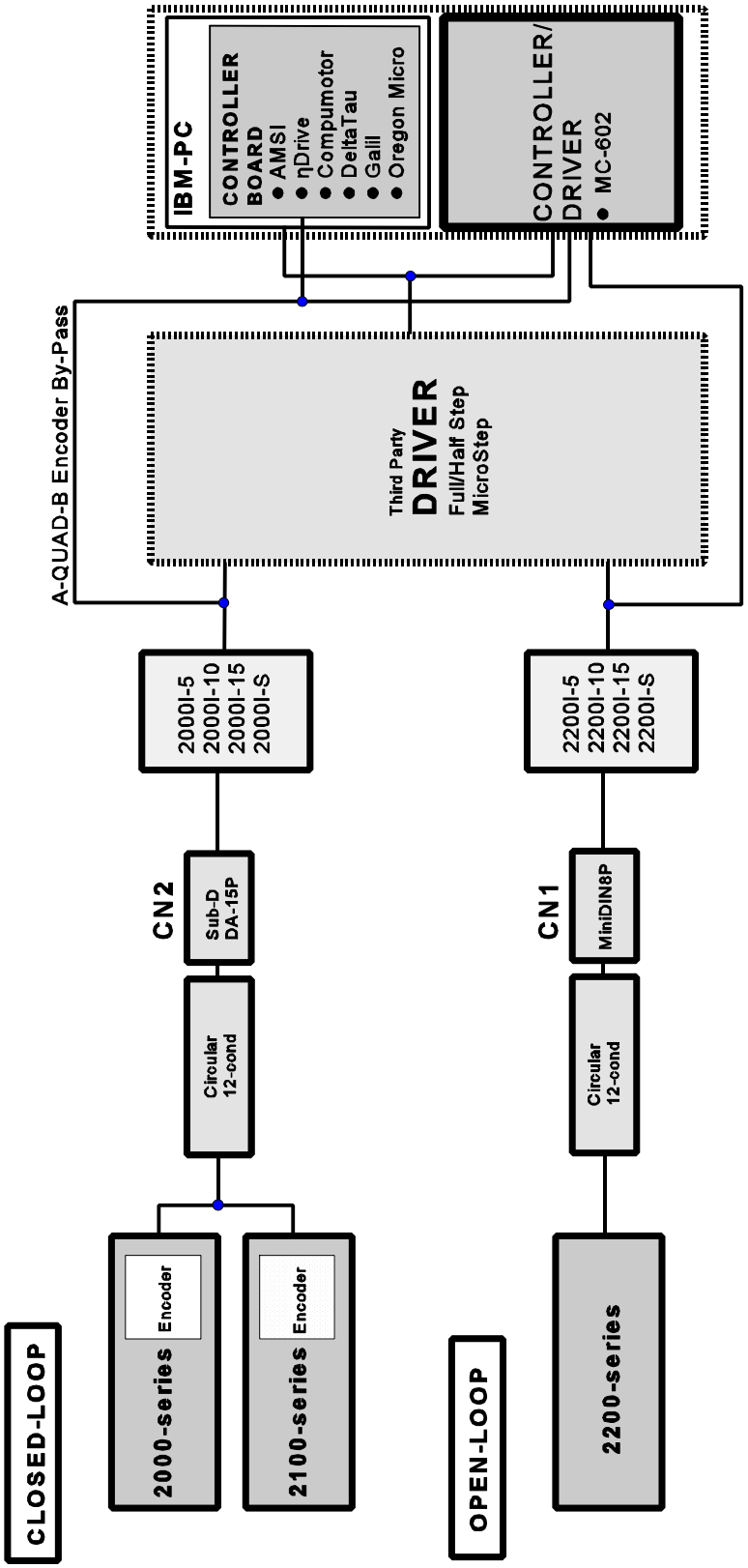


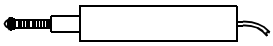


1000-Family COMPONENT INTERCONNECT



2000-Family COMPONENT INTERCONNECT





ACTUATORS

DC MOTOR

LINEAR[1]

Item	Page	Price
1000-series Closed/Open-loop		
1000-05	L12	
1000-1	L12	
1000-2	L12	
1000-4	L12	
1000-6	-	
[2]-V		
1100-series Closed-loop		
1100-025	L18	
1100-05	L18	
1100-1	L18	
1100-2	L18	
1100-4	L18	
1100-6	L18	
1100-8	L18	
1100-10	L18	
1100-12	L18	
-V		
1200-series Open-loop		
1200-025	L22	
1200-05	L22	
1200-1	L22	
1200-2	L22	
1200-4	L22	
1200-6	L22	
1200-8	L22	
1200-10	L22	
1200-12	L22	
-V		

ROTARY[4]

Item	Page	Price
1400-series Closed-loop		
1400-1313	-	
1400-1616	-	
1400-1624	-	
1400-1717	-	
1400-1724	-	
1400-2233	-	
1400-3540	-	
1400-3557	-	
-V		
1450-series Open-loop		
1450-1313	-	
1450-1616	-	
1450-1624	-	
1450-1717	-	
1450-1724	-	
1450-2233	-	
1450-3540	-	
1450-3557	-	
-V		
ANALOG VELOCITY SERVOS		
SER3000	-	
-ENC	-	
SER3010	-	
-ENC	-	
-EB	-	
Applies to All		
-TTL	-	NC

STEPPING MOTOR

LINEAR[5]

Item	Page	Price
2000-series Closed/Open-loop		
2000-05	S32	
2000-1	S32	
2000-2	S32	
2000-4	S32	
-V		
2100-series Closed-loop		
2100-025	S33	
2100-05	S33	
2100-1	S33	
2100-2	S33	
2100-4	S33	
-V		
2200-series Open-loop		
2200-025	S34	
2200-05	S34	
2200-1	S34	
2200-2	S34	
2200-4	S34	
-V		
ROTARY[5]		
Closed-loop		
2400-AM1524	-	
-V	-	
Open-loop		
2450-AM1524	-	
-V	-	

OPTIONS/ACCESSORIES

Actuator-Related

-B	A46	
-NB1	A46	
-NB2-3	A46	
-PPA	A46	
-PP1-4	A46	
-PP5	A46	
-SD	-	
-TTL	-	
-ZB	-	

Interconnect Cables

1000I-5	-	
1000I-10	-	
1000I-15	-	
1000I-S	-	
1200I-5	-	
1200I-10	-	
1200I-15	-	
1200I-S	-	

2000I-5	-	
2000I-10	-	
2000I-15	-	
2000I-S	-	
2200I-5	-	
2200I-10	-	
2200I-15	-	
2200I-S	-	

DC-MOTOR CONTROLLERS

MANUAL

Item	Page	Price
1000-series [Hybrid-loop]		
INT-series [Integrated]		
1000INT1+110P	-	
1000INT2+110P	-	
1000INTJ+110P	-	
+220P	-	
MOD-series [Modular]		
1000M+110P	-	
1000EM	-	
1000S	-	
1000D	-	
1000JM	-	
1000R	-	
+220P	-	

Item	Page	Price
1200-series [Open-loop]		
1200SC+110P	-	
1200SCC+100P	-	
-1616	-	
-1624/1717/1724	-	
-2233	-	
-3540	-	
-3557	-	
1200J+110P	-	
1200JC+110P	-	
-1616	-	
-1624/1717/1724	-	
-2233	-	
-3540	-	
-3557	-	
+220P	-	
1200P	-	

COMPUTER-CONTROLLED

Item	Page	Price
CONTROL2 [Closed-loop]		
1000C2-2	-	
1000C2-4	-	
1000C2-6	-	
1000C2-488	-	
1000C2-JSB	-	
1000C2-RM	-	
1000C2-MD	-	
1000C2-OM	-	

CONTROL3 [Closed-loop]

OEM board set) custom software set-up charge. Request separate price list.

TERMS
Net 30 days to qualified purchasers.
F.O.B. Arleta, CA, USA
Domestic USA pricing only.
Ask for export pricing.

Prices subject to change without notice) please verify.

PRICING NOTES

1 One price for all motors (1616, 1624, 1717, 1724) and gearhead (16/5, 16/7) ratios. Does not include servo SER3000-series.

2 -V = Vacuum compatible

3 Special Order

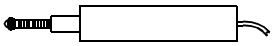
4 One price for all gearhead (16/5, 16/7) ratios. Does not include servo SER3000-series.

5 One price for all gearhead (15/5) ratios.

QUANTITY DISCOUNTS

For multiple quantities of any single item, group of similar items, or systems per purchase order for deliveries during 12 months.

Quantity			Discount
	)	1	0%
2	)	4	5%
5	)	9	9%
10	)	19	15%
20	)	49	25%
50	)	99	40%
	>	99	55%



WARRANTY STATEMENT

INTRODUCTION

All products interfaced to non-TS Products controllers have a limited warranty because faulty controllers or miss-wiring can damage the actuator, motor, encoder, and servo electronics. For both DC-motor and Stepping-motor Actuators, the user is fully responsible for correct connection to a properly-operating Controller functioning within the operating limits of the Actuator. When using controllers purchased from TS Products, the warranty is not limited since we warranty the total motion system..

Limit-of-Travel Actuator products depend on the Controller and/or Servo to appropriately stop the motor. While the 2000-family has built-in Hall-effect sensors to detect the limit-of-travel, the 1000-family has no sensors) it relies on external electronics to monitor motor current under a feedback arrangement to infer a limit-of-travel. In either case, the Actuator does not stop itself!

Motor Current Both DC motor and Stepping motor Actuators with relatively high gear ratios can easily produce high thrusts. These thrusts will damage gearhead teeth if the motor current is not deliberately limited. In addition, both styles of motors will be damaged from high temperatures due to high current flow through the motor windings. Neither the actuator nor the Analog Velocity Servo are self-protecting!

MODIFICATIONS

No modifications are permitted without prior written approval.

SUMMARY

When operating from non-TS Products' Controllers and Servos, both the 1000 and 2000-family of actuators are guaranteed against defects in materials and workmanship for one (1) year from delivery only for the following defects:

1. Bond failure between gearhead output shaft and leadscrew;
2. Minimum travel, thrust, and maximum no-load velocity;
3. Housing defects;
4. Cabling defects.

When operating from TS Products' Controllers/Servos, our warranty is almost unlimited except that we do not guarantee that our products will function in the customer's particular system to the customer's expectation or satisfaction. We only warranty that our products will function as expressly specified in the particular Operator's Manual in effect at time of delivery. TS Products is not liable for any customer assumptions of other performance specifications except those agreed-to in writing by TS Products. We do not have a Return for Refund policy due to the custom nature of each product.

WARRANTY STATEMENT

For 1-year after delivery, TS Products will either repair or replace, on its option, the defective component if returned to the factory in Arleta, CA. This warranty shall not apply to defects resulting from improper maintenance, misuse (as described above), nor unapproved modifications. Warranty is limited to cost of the defective component and in no way can it be construed to cover damage to any external subsystem or component, penalties on customer for late delivery, or customer-supplied components. Obtain a Return Material Authorization (RMA) number from TS Product prior to shipping defective component to factory. No warranty repairs will be made on equipment if original purchase payment is past due.

CONTROLLER SUMMARY

DC-Motor

Open Loop

1200SC Controls 1-of-4 Linear/Rotary Actuators (DC motors) with DIRECTION, VELOCITY, LIMIT INDICATIONS, JOG/SLEW, and MOTOR SELECTION controls. Housed in a 4"x6"x3" slope-front enclosure, it has a convenient 110vac wall-mount and 220vac table-top power supply. A built-in Analog Velocity Servo with 20:1 speed range provides constant velocity within the servo window. Available for 1616 through 3557 MicroMo or equivalent motors. Unused channels are shorted to themselves to provide BEMF braking. Internal Limits-of-Travel circuitry senses motor conditions with adjustable sensitivity and backs-off offending Stall or Limit. Computer version [SCC] permits PC's printer port to control and read most functions.

1200J 2-axis Joystick controls two Linear/Rotary Actuators simultaneously with dual built-in Analog Velocity Servos together with Stall/Limit sensing electronics. Housed in a 4"x6"x3" slope-front enclosure, it has SLOW/FAST and LIMIT INDICATORS. Computer version [JC].

Hybrid

The Hybrid controller combines open-loop control with position display from encoder built into 1000, 1100, 2000, 2100, 1400, 2400 Actuators.

1000INT-family

This family of controllers integrates separate controller functions into a single unit. In contrast, the 1000MOD-series is an assembly of modules.

1000INT1 Single axis controller housed in a 4"x6"x3" slope-front enclosure with VELOCITY, DIRECTION, JOG, and POSITION DISPLAY MULTIPLIER and CLEAR functions. Produces a ±10vdc Command Velocity Voltage for an external servo. Limit handling senses STALLs and LIMITs-OF-TRAVEL from Linear/Rotary Actuators. 110vac wall-mount or 220vac table-top power supply.

1000INT2 Dual axis controller housed in a slope-front 9"x6"x4" enclosure with independent controls and displays for 2 axes.

1000INTJ Dual axis Joystick Controller with POSITION DISPLAY housed in a slope-font 9"x6"x4" enclosure.

1000MOD-family

This modular 1000-series controllers mixes SPEED CONTROL, POSITION DISPLAY, and POSITION ENTRY modules for 1 to 3 axes into a single enclosure. In contrast to 1000INT controllers, functions can be easily added as requirements change. While the basic unit is housed in an 8"x9"x3" enclosure, the Position Entry Module adds a 2"x2"x9" module on top. The Position Entry modules provides an elementary method of stopping motion when a programmable coordinate is reached. The power supply is a 110vac wall-mount or 220vac table-top.

Order#	Description
1000M	Mainframe
1000S	Speed Controller
1000D	Position Display
1000R	Remote Control
1000EM	Position Entry Mainframe
1000JM	Joystick Speed Controller

Closed Loop

CONTROL2 General-purpose microcomputer controller for up to 6-axes of DC motors with external servos and A-QUAD-B encoders. An interface between computers and actuators, the CONTROL2 has a library of more than 50 motion commands used over RS-232 or IEEE-488 communications busses concurrently. Fundamental movement is closed-loop trapezoidal with automatic backlash compensation. Housed in an 8"x10"x16" enclosure, CONTROL2 has a programmable built-in front panel joystick, jog/slew buttons, and activity and limit indicators as well as a built-in power supply. Motion programs can be executed from internal battery backed-up memory. Extensive I/O controls and reads external events.

CONTROL3 2"x10"x11" board-set designed for OEM environments with multiple quantities, CONTROL3 can control system functions as well as provide closed-loop position of up to 32 axes. A REMOTE PANEL permits operator interface for position display and Menu Tree commands functions. Custom programming for each application draws on library of motion control functions. Set-up programming typically necessary to match environment.

Servo

SER3000 Principally for ironless-core DC motors, the SER3000-series Velocity Servos are balanced-bridge type for fast response, dynamic braking, low EMI, and absolutely no acoustic noise. Sensing the motor's BEMF provides feedback for constant, programmable motor velocity independent of load. At rest, the servo resists external forces. Weighing less than 2 oz, the 1.7"x3.7" PCB mounts into a 2"x4"x1" Vero box. A built-in 10-pin ribbon cable connector accepts standard MicroMo connectors for motors with HE encoders. Normal connection to motor is made through 8-pin MiniDIN and to controller through DE-9P connectors. MicroMo 1016-2233 motors use the 1-amp (18v max) version with National's µA759 Power Amplifier (SER3000). 3557 Super motors use the 5-amp (40v max) continuous or 10-amp intermittent version (SER3010) with Burr-Brown's OPA541.

Stepping Motor

2000-family of Stepping Motor products can be controlled by standard Stepping Motor Drivers and Controllers. We recommend AMSI for low-cost entry-level or ?Drive for advanced control.

CUSTOM MOTION SYSTEMS

Imagine for a moment that you need a custom motion subsystem! It must handle or assist in a production/assembly/alignment task. The motion must be compact, smooth, fast, time-dependent, and high-resolution. The transport mechanism must fit around existing equipment and carry your load with a 100% duty cycle. In addition to collecting data, your existing PC [IBM, HP, MAC] must initialize the motion and monitor performance.

Hire TS Products to take full responsibility for your motion subsystem!

Written Motion Specification

We interview you!

Write custom SOFTWARE for your computer

Prepare Engineering Drawings

Document the final configuration

INSTALL and TRAIN

We assume the RESPONSIBILITY!

Select the best hardware

- Translation stages ✓
- Rotary tables ✓
- Motion Controllers ✓
- Linear Actuators ✓
- Large and small motors ✓
- Cabling and connectors ✓

DIAMOND MOTION

P.O. Box 1225
Port Angeles, WA 98362-0227 USA
360-417-9791 Fax 360-417-9794

http://www.diamondmotion.com
sales@diamondmotion.com
thefrontdoor@diamondmotion.com

The Micro-positioning Specialists!